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Indicators of the Environmental Impacts of Transportation

Updated Second Edition

Foreword

This is the second edition of a report issued by the U.S. Environmental Protection Agency on the environmental impacts of transportation in the United States. This report compiles national-level data on the effects of transportation on all environmental media — air, water, and land — and highlights environmental statistics that can be used to assess the magnitude of transportation impacts and track trends over time. It addresses a broad range of transportation-related activities, including infrastructure construction, vehicle and equipment manufacture, travel, operations and maintenance, and disposal. The document is designed as a reference for policy-makers, researchers, and others interested in the multi-media impacts of our nation's transportation system.

This report was prepared under contract #68-W4-0041 for the U.S. Environmental Protection Agency, Office of Policy, Energy and Transportation Sectors Division, by Hagler Bailly Services, Inc. EPA is pleased to acknowledge the input received during the initial report preparation process from representatives of the U.S. Department of Transportation (Office of the Secretary, Bureau of Transportation Statistics, Federal Aviation Administration, Federal Highway Administration), the U.S. Department of Energy, and the Center for Transportation and the Environment at North Carolina State University.

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1. INTRODUCTION

1.1 BACKGROUND

Although the nation's transportation system provides a wide range of benefits, it also generates unintended adverse impacts on environmental quality and human health. Since the late 1960s and early 1970s, increased recognition of environmental and health problems has led to significant policy actions aimed at reducing these impacts. Legislation on clean air and water, protection of environmentally sensitive habitats and species, noise control, and regulation of hazardous materials transportation, among others, have been successful in addressing some transportation impacts.

This report discusses transportation's impacts on the natural environment and provides quantitative estimates of those effects at a national level. It provides a comprehensive compilation of data on all of the environmental implications of the transportation sector. The document addresses all primary modes of transportation in environmental media and covers a wide range of transportation activities — infrastructure construction, vehicle maintenance, travel, operations and maintenance, and disposal. This document presents data that can be used as "indicators" of the magnitude of environmental problems associated with transportation.

PURPOSE

EPA intends this document to serve as a resource for transportation and environmental decisionmakers, researchers, and the public. The report compiles statistical information from many environmental data sources and identifies information that can be used to track environmental performance. EPA has three goals for this document:

1) To describe the full range of environmental impacts associated with transportation;

2) To identify quantified national-level data on these impacts; and

3) To assess gaps in data and limitations of various indicators.

This is the second edition of EPA's compilation of environmental indicators for the transportation sector. Since the first version of this report was completed in 1996, a large amount of new environmental information has become available. Environmental databases have been updated, methodologies have been revised, and new studies have been conducted. This document updates the environmental data and has been restructured to improve the presentation and discussion of environmental indicators.

SCOPE OF STUDY

When people think about the environmental impacts of transportation, they often think about habitat loss from road construction and air pollution from motor vehicle use. They often fail to consider other environmental consequences associated with transportation, such as the impacts of vehicle manufacture and supporting facilities. *This study is unique in its attempt to quantify the full range of environmental impacts caused by transportation.* It examines the full range of environmental consequences associated with four modes of transportation and for the transportation sector as a whole. The "life-cycle" of transportation activities and facilities is examined, although some upstream and downstream effects are not emphasized. This study attempts to address the full range of environmental issues associated with transportation at a summary level.

MODES OF TRANSPORTATION

This report presents environmental information for four modes of transportation:

- ***Highway*** **-** The highway system includes road infrastructure, and on-road motor vehicles, including automobiles, light-duty trucks, buses, and freight trucks.
- ***Rail*** **-** The rail system includes intercity passenger rail (Amtrak), rail transit (light rail, heavy rail, and commuter rail), and freight rail.
- ***Aviation*** **-** The aviation system includes general and commercial aviation.
- ***Maritime*** **-** The maritime system includes water-borne freight, as well as passenger ferries and recreational boats.

In addition, this report compiles data on environmental impacts for the transportation sector as a whole, and identifies the contribution of travel and transportation-related industries in comparison to other sectors of the economy.

LIFE-CYCLE OF TRANSPORTATION ACTIVITIES

This report addresses the life-cycle of transportation activities and facilities:

- ***Infrastructure construction*** **-** Construction and development of transportation facilities, such as roadways, railways, airports, and navigation channels;
- ***Vehicle manufacture*** **-** Production of vehicles and parts (including motor vehicles, railcars and locomotives, aircraft, and ships and boats);
- ***Travel*** **-** Vehicle operations to transport people and goods;
- ***Operations, maintenance and support*** **-** Activities to support travel, such as application of deicing chemicals, as well as operation of facilities to support travel, such as gas stations, airport terminals, and marinas; and
- ***Disposal*** **-** Disposal or recycling of vehicles, parts, and facilities.

The upstream effects from ***fuel processing, storage, and distribution*** are also discussed briefly.

ENVIRONMENTAL CONSEQUENCES

This report examines the effects of transportation on all environmental media — air, water, and land. Because pollutant releases can have multi-media effects, this report generally presents environmental information by pollutant. It addresses:

- ***Criteria air pollutants*** —Pollutants that adversely affect human health and welfare: carbon monoxide (CO), ground level ozone (O_3) and its precursors, lead (Pb), nitrogen dioxide (NO_2), particulate matter (PM), and sulfur dioxide (SO_2);

- ***Toxics* —** Pollutants that cause or may cause cancer or other serious problems, such as reproductive effects or birth defects, or adverse ecological effects;
- ***Greenhouse gases*** — Compounds that contribute to global climate change by trapping heat within the Earth's atmosphere: carbon dioxide, methane, nitrous oxide, and several other compounds;
- ***Chlorofluorocarbons and stratospheric ozone depletion*** — Man-made chemicals that are known to deplete stratospheric ozone;
- ***Habitat and land use*** — Adverse effects on wildlife, ecosystems, and endangered species such as habitat destruction or fragmentation;
- ***Water quality and aquatic resources* —** Adverse effects to the water quality in lakes, streams, rivers, or groundwater and the ecosystems that depend on them;
- ***Hazardous materials incidents*** — Releases of hazardous materials during transportation;
- ***Noise*** — Unwanted sounds that interfere with communication or cause adverse health effects; and
- ***Solid waste*** — Disposal of materials and parts through recycling, reuse, or shipment to landfills.

IMPACTS DE-EMPHASIZED OR EXCLUDED

We have limited the scope of this study to the direct impacts of transportation infrastructure and activities. It does not address the full indirect, upstream, downstream, and historical impacts. Impacts de-emphasized or excluded include:

- ***Certain long-run and cumulative impacts*** — For example, no analysis of the historical destruction of wetlands and forests to build existing highways or the environmental benefits that would accrue if land use reverted to historical uses;
- ***Upstream impacts*** — Some examination of the manufacture of vehicles, but not raw inputs from the steel or chemical industries; limited evaluation of gasoline/oil refining;
- ***Downstream impacts*** — Some consideration of the disposal of tires, waste oil, and vehicles, but not a full analysis of all disposal impacts, such as wastes resulting from airport operations or industrial processes;
- ***Indirect impacts*** — No analysis of the effects associated with industrial or residential development that may occur near new transportation facilities;
- ***Local impacts* —** No analysis of impacts in specific watersheds, urban areas, or regions;
- ***Cultural, aesthetic, and social impacts* —** No analysis of these impacts; and
- ***Resource depletion impacts* —** Nonrenewable resource depletion (e.g., use of fossil fuels by motor vehicles) is not addressed as a separate issue because it does not damage the environment *per se.*

REPORT STRUCTURE

A number of changes have been made since the original edition to improve the report's utility. They reflect input from a panel of environmental experts from the U.S. Department of Transportation, U.S.

Department of Energy, and academic institutions who were asked to provide input on the organization of the report. They include:

- ***More focus on national statistics that can serve as indicators*** — This report focuses solely on environmental data that reflect national impacts; local examples are not presented in this report. In addition, the report presents trend data where available to provide a measure of progress and direction.
- ***More focus on context*** — Context is important in determining how problematic environmental impacts are and how much progress is being made. For example, the share of impacts from transportation sources affects how much importance should be placed on these effects (e.g., if a transportation source is a very small share of total releases, we may assign less importance to controlling this source). Exposure to pollution and resulting health and welfare impacts affect the importance of pollutant releases (e.g., if most areas of the nation attain air quality standards for lead, emissions of lead from aircraft may not be a significant health issue). Finally, when examining environmental impacts, it is important to be aware of the level of activity producing the effect (e.g., significant reductions in air pollutant emissions from motor vehicle travel are more striking given rapid increases in vehicle travel).
- ***More focus on data issues*** — The report includes a discussion of the major databases and data sources available. It highlights the limitations and weakness in these sources, as well as gaps in environmental information.
- ***Compilation of the impacts of the entire transportation sector*** — The report includes a chapter that summarizes the full transportation sector contribution to each environmental issue. In the initial edition of this report, impacts were addressed only in separate chapters for each mode of transportation, which did not allow for easy review of the total impact of transportation or comparisons of modal impacts. Although a number of reviewers suggested more modal comparisons, comparisons of effects per passenger mile or ton mile are not included in this report.[1]

This report is structured as follows:

Introduction

Chapter 1: Introduction — The report begins with a brief introduction to environmental indicators, discusses the strengths and weaknesses of various types of indicators, and presents information on data availability and limitations.

Transportation Environmental Indicators

Chapter 2: Transportation Indicators Summary — This chapter is organized by environmental topic and summarizes the contribution of transportation as a whole to each impact, as well as the contributions of specific transportation sources (e.g., modes and sub-modes).

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[1] Effects per passenger mile or ton mile may vary significantly in different places, by time of day, and by type of trip. Also, the modes are not exact substitutes for each other; the levels of service on the modes differ and the types of trips and types of freight carried by each mode differ. Given the level of effort required for this compilation and distinct nature of the research, the U.S. Environmental Protection Agency will undertake a separate research effort to develop such comparisons.

The report goes on to provide more detail on environmental impacts associated with each mode of transportation. Each chapter presents a discussion of environmental effects and quantified indicators, organized by type of transportation activity.

Chapter 3: Highway Indicators

Chapter 4: Rail Indicators

Chapter 5: Aviation Indicators

Chapter 6: Maritime Indicators

Data Issues

Chapter 7: Data Availability and Next Steps — This chapter identifies the major environmental databases used to track the environmental impacts of transportation and develop the indicators presented in this report. It also highlights data gaps and potential next steps.

1.2 DEFINITION OF INDICATORS

The term "indicator" is used throughout this report to refer to quantitative estimates of the magnitude or severity of a problem or issue. Indicators may be based on measurements or modeling. National estimates of environmental impacts are typically derived from modeling or other methods of extrapolation from local or site-specific data.

WHAT INDICATORS CAN DO

Indicators can be extremely useful in guiding transportation and environmental policy discussions. They can:

- ***Assess the magnitude of environmental problems*** — Indicators can highlight environmental problems by providing information on the largest sources of environmental problems. By identifying the full range of impacts, indicators can also provide a broad perspective on environmental issues.
- ***Help set priorities*** — By identifying problems and the share of problems caused by specific activities, indicators can help set priorities, particularly for research and among issues needing new or improved policies.
- ***Develop performance measures and track progress toward environmental goals*** — Ideal indicators can be tracked consistently and reliably tracked over time, and used to develop measures of environmental performance and track progress toward meeting targets.
- ***Educate policymakers, transportation and environmental stakeholders, and the public*** — By providing information on the contribution of transportation to environmental problems, indicators can help inform the public about environmental issues in transportation.

WHAT INDICATORS CANNOT DO

It is important to keep in mind that indicators can be misapplied so care should be taken to consider their limitations. Briefly, indicators cannot serve the following purposes:

- ***Isolate effects of individual regulations* -** Indicators may show improvement in a certain area (e.g. mobile source air emissions and air quality) but generally will not describe the root causes underlying that improvement. In other words, they may show the net results, but not why the situation improved. For example, indicators may show decreasing air emissions, but these could result either from policy-driven per-mile emissions reductions or from reduced travel due to recession or rising fuel prices.
- ***Provide an economic analysis* -** Indicators do not provide information about the benefits of travel and related activities. For example, deicing salt application has significant environmental impacts, but is beneficial in allowing travel and saving lives during storms. Indicators say nothing about the costs or benefits of policies that might alleviate such environmental impacts.
- ***Define acceptable levels of impact or rates of progress* -** Indicators may describe objectively the amount of impact or rate of progress, but subsequent policy decisions must be made about whether a given impact or rate of progress is acceptable. Indicators of environmental impact should not be used alone for setting priorities for regulatory action. Instead, cost-effectiveness of policy options should be considered.

TYPES OF INDICATORS

This report uses a three-stage framework for identifying environmental indicators:

- Outcomes
- Outputs
- Activities

These stages are shown in Figure 1-1. Transportation-related activities — infrastructure construction, vehicle manufacture, travel, maintenance and support, and disposal — result in releases of pollutants or damage to habitats. These outputs, in turn, have human health or welfare effects.

Indicators can be developed at each of these stages. Ultimately, people care about environmental outcomes; however, because of data gaps and the difficulty associated with isolating transportation's share of an impact from that of other sources, outcome indicators often are not available. Each type of indicator is described below with a short synopsis of strengths and weaknesses and examples of indicators.

OUTCOME INDICATORS

Indicators of outcomes are measures of end results. They provide quantitative information on health, environmental, and welfare effects resulting from transportation. Outcome indicators are desirable because they provide information about the effects that people care about. Unfortunately, quantified estimates of environmental outcomes are often unavailable or uncertain. Also, it is frequently difficult to separate the effects of transportation from other sources. In practice, many outcome indicators are subject to uncertainty or are qualitative in nature. For example, the number of states identifying highways as a source of habitat loss could be considered an outcome indicator because it provides a sense of magnitude about highway construction impacts on ecosystems. However, states may determine sources of habitat loss differently and the indicator does not say exactly how much habitat acreage has been lost. Other examples of outcome indicators include:

- Number of wildlife deaths

- Changes in the abundance of species
- Number of cases of illness or mortality

OUTPUT INDICATORS

Output indicators provide information on the amount of releases, emissions, or incidents that are associated with environmental damage, or the amount of land or resources consumed. They do not quantify the actual damage that takes place, but provide information about outputs that are known to be associated with human health, environmental, or welfare effects. Measurements, models, or other methodologies are often available to estimate outputs consistently over time. Examples of outcome indicators include:

- Quantity of pollution emitted or released
- Number of hazardous materials incidents
- Levels of noise

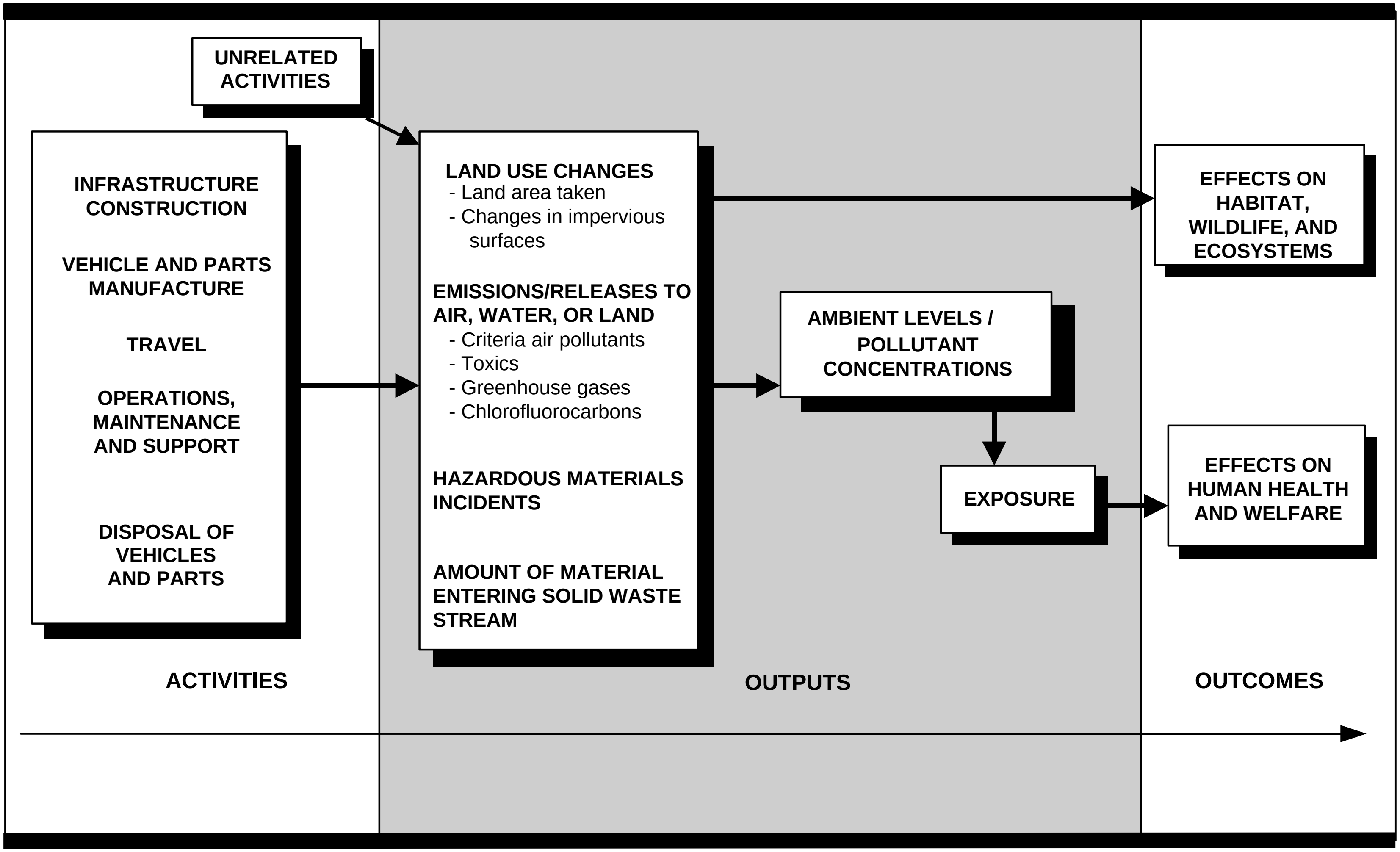
ACTIVITY INDICATORS

Activity indicators provide information about the extent of activities that are known to produce adverse environmental effects. Activity data tend to be the most readily available of all indicators. Examples include:

- Number of lane miles constructed
- Number of vehicles manufactured
- Number of vehicle miles traveled
- Quantity of deicing chemicals purchased (minus inventories)

While activity data are readily available, they are limited as environmental indicators because activities do not always correspond directly to environmental harm. For example, all else equal, increasing vehicle travel should produce greater quantities of pollutant emissions; however, motor vehicle emissions have been declining since the 1970s despite significant increases in vehicle travel because emission control technologies have improved. Likewise, a number of industries have significantly reduced pollutant outputs through improved technologies and pollution prevention.

Figure 1-1. Effects of Transportation and Related Activities on the Environment



IDEAL INDICATORS OF TRANSPORTATION IMPACTS

An ideal indicator:

- ***Focus on end results*** — Information should be provided on outcomes, such as number of illnesses caused, not outputs or activities that cause outcomes
- ***Isolate transportation's share of the impact*** — The indicator should identify the effect of transportation rather than providing an estimate of environmental quality that may depend on numerous sources
- ***Be reasonably certain*** — Although modeling may be necessary to estimate the national effect, the indicator should be generally agreed upon as reasonably accurate and reliable
- ***Be stated in meaningful units*** — The indicator should be presented in units that allow comparison to other sources of a problem or to a goal

In practice, there are tradeoffs between these traits. Although outcome indicators are the most desirable type of environmental information, data on environmental outcomes is typically not available or tracked consistently. When outcome measures are available, it is often impossible to identify the contribution of transportation separately from other sources. For example, one measure of outcomes for air quality is the number of people living in areas that do not meet one or more of the national ambient air quality standards (NAAQS). However, even if we know how many people are exposed to poor air quality, this figure does not tell us about the contribution of transportation to the problem. The estimation of health and welfare effects, such as the number of cases of respiratory problems associated with transportation-related pollution, can also be the subject of significant debate.

In general, the *best available* indicators of transportation's impact tend to be output indicators — measures of the quantity of pollution emitted or released, or the number of incidents known to cause environmental damage. Estimates of outputs tend to be estimated, reported, or tracked more consistently than outcome measures. As a result, this report focuses primarily on output indicators. It is important, however, to keep end results in mind when examining output indicators. Not all emissions or releases are equal; health and environmental results depend on exposure to pollution and other factors, such as the location and time of releases. In this report, activity indicators are presented when output data are unavailable.

1.3 PRESENTATION OF ENVIRONMENTAL INDICATORS

The following sections of this report present information on the environmental consequences associated with four modes of transportation: highways, rail, aviation, and maritime transport. A summary chapter highlights the effects of transportation on the environment and the relative magnitude of impacts from each mode. Individual chapters for each mode follow the summary chapter. In the modal chapters, subsections focus on the effects of each transportation activity — infrastructure construction; vehicle manufacture; travel; operations, maintenance, and support; and disposal.

Each environmental impact is presented with:

- ***Description of Impact*** — A brief discussion of environmental effects relating to transportation activities. The focus here is on processes that cause environmental outputs (generally, emissions, releases, or incidents), not on why the outputs are harmful (e.g., a brief discussion of sources of air pollutant emissions from aviation travel, not how different air pollutants affect health and welfare). An overview of each pollutant and the contribution of transportation is provided in the summary chapter at the end of this report.
- ***Impact Factors*** — A list of some of the primary factors that affect the magnitude of environmental impact.
- ***Indicators of Environmental Impact*** — The key indicators that have been quantified are presented. Because of data availability, output indicators predominate. Outcome indicators are presented when available; activity measures are presented when output information is not available.

2. TRANSPORTATION INDICATORS SUMMARY

This chapter summarizes national indicators of the environmental impacts of transportation. Transportation is defined broadly here to include transportation infrastructure construction and travel on the nation's transportation system, as well as related activities, such as transportation equipment manufacturing, infrastructure maintenance, and vehicle support. This chapter identifies the contribution of the transportation sector as a whole to specific environmental problems. Quantitative indicators and trends are presented, as available.

The availability of data for tracking the environmental impacts of transportation varies greatly for different aspects of the environment and types of transportation activities. Air pollution and greenhouse gases from travel are among the most well understood impacts of transportation, and estimates of emissions from travel have been quantified by mode. Many other environmental effects, such as the impacts of transportation systems on habitat fragmentation and water quality, have not been fully quantified nationally. In most cases, impacts associated with activities such as transportation equipment manufacturing and facility maintenance have not been tracked consistently or aggregated to the national level.

In this chapter, indicators are presented on nine environmental topics:

- Criteria air pollutants;
- Toxics;
- Greenhouse gases;
- Chlorofluorocarbons and stratospheric ozone depletion;
- Habitat and land use;
- Water quality;
- Hazardous materials incidents;
- Noise; and
- Solid waste.

This chapter compares the relative contribution of different transportation sources, modes, and activities to each of these environmental issues. The chapters following this one provide more detail on each mode of transportation: highway, rail, aviation, and maritime.

2.1 CRITERIA AIR POLLUTANTS

Criteria pollutants are those for which the U.S. Environmental Protection Agency (EPA) has established National Ambient Air Quality Standards (NAAQS) to protect public health and welfare. There are seven criteria pollutants with primary standards: ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), lead (Pb), particulate matter with aerodynamic diameter less than or equal to 10 micrometers (PM_{10}), and particulate matter with aerodynamic diameter less than or equal to 2.5 micrometers ($PM_{2.5}$).[1] Health effects of these pollutants vary but include respiratory and cardiopulmonary problems, headaches, reduced learning ability, and premature mortality. These pollutants also contribute to acid rain, reduced agricultural yields, harm to vegetation, damage to building materials, and decreased visibility.

The effect of motor vehicles on air quality is one of the most recognized environmental implications of transportation. Recognizing the magnitude of the problem, regulations under the Clean Air Act and Amendments have dramatically reduced motor vehicle emissions of major criteria pollutants. The U.S. Environmental Protection Agency tracks air quality trends through an extensive monitoring network and maintains a program to estimate and track emission trends. Emission estimates provide an indication of how much pollution is being released by different types of sources, while monitored air quality data provide an indication of the severity of an air quality problem.

Monitoring data from across the U.S. show dramatic decreases in air pollutant concentrations since the early 1970s. Between 1978 and 1997, concentrations of ozone (one-hour) have fallen by 30 percent, carbon monoxide concentrations have fallen by 60 percent, and lead concentration have fallen by 97 percent. Between 1988 and 1997, the total number of days exceeding air quality standards has dropped 56 percent in Southern California and 66 percent in the rest of the United States.[2] These dramatic improvements in air quality have been due in part to significant reductions in transportation-related emissions, as presented below. Still, air pollution problems remain through large parts of the country, and transportation remains a significant contributor to this problem.

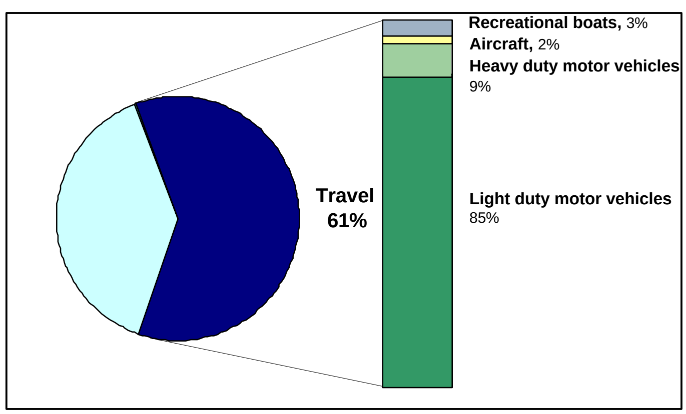
EMISSIONS FROM TRAVEL

Transportation contributes to air pollution primarily through the release of pollutants during the fuel combustion process. Pollutants are also emitted during the refining and processing of fuels and fuel evaporation. Transportation sources consumed about 66 percent of the petroleum used in the U.S. in 1997.[3]

Carbon Monoxide

Combustion of fuel during travel is a major source of carbon monoxide (CO) emissions, contributing about 61 percent of all CO emissions nationwide. Motor vehicles are the primary transportation source of CO emissions, contributing about 94 percent of travel emissions.

Figure 2-1: Share of CO Emissions from Transportation, 1997

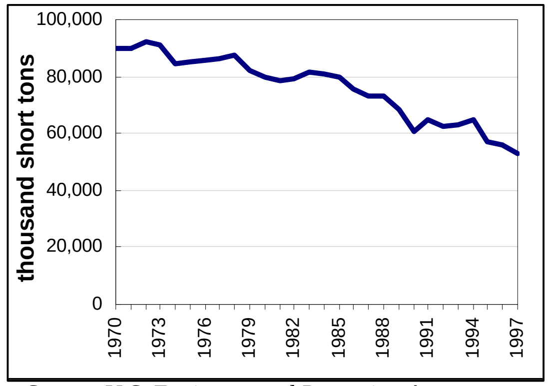


Source: U.S. Environmental Protection Agency. *National Air Pollutant Emission Trends, 1900-1997.*

[1] The new PM_{10} and ozone standards are on hold under court order as of the date of publication of this report.
[2] U.S. Environmental Protection Agency. *National Air Quality and Emission Trends Report, 1997.* pp. 9, 63.
[3] U.S. Department of Energy. *Transportation Energy Data Book: Edition 18.* Table 2.5.

Carbon monoxide has become less of a national air quality problem over the past twenty years as CO concentrations in the air have decreased by 60 percent nationwide. In 1997, only three counties (Los Angeles County, CA; Fairbanks, AK; and Imperial County, CA) had monitoring sites that failed to meet the NAAQS for CO. Declining transportation emissions have contributed significantly to the reduction in total CO emissions. Carbon monoxide emissions from transportation fell by 41 percent between 1970 and 1997, compared to an 11 percent reduction in emissions from non-transportation sources over this time period. Contributors to reduced CO emissions from motor vehicles include national standards for tailpipe emissions, new vehicle technologies, and use of oxygenated gasoline.

Figure 2-2: CO Emissions from Travel, 1970-1997



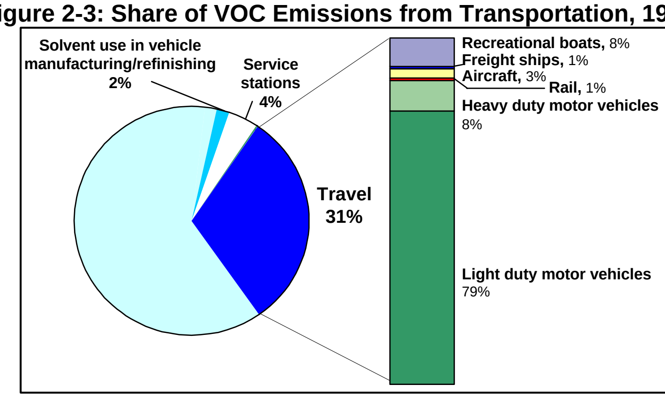
Source: U.S. Environmental Protection Agency. *National Air Pollutant Emission Trends, 1900-1997.*

Although exceedances of the CO standard have fallen significantly, high concentrations of CO often occur in areas with heavy traffic congestion. In cities, as much as 95 percent of all CO emissions may come from on-road vehicles.

Ozone and its Precursors

Ground level ozone (O_3) is the most pervasive air pollution problem in the U.S. Despite a 30 percent drop in one-hour ozone concentrations in the air between 1978 and 1997, about 47.9 million Americans lived in 77 counties with ozone concentrations above the pre-existing NAAQS in 1997. About 101.6 million Americans lived in counties with ozone concentrations above the level of the new eight-hour ozone NAAQS.

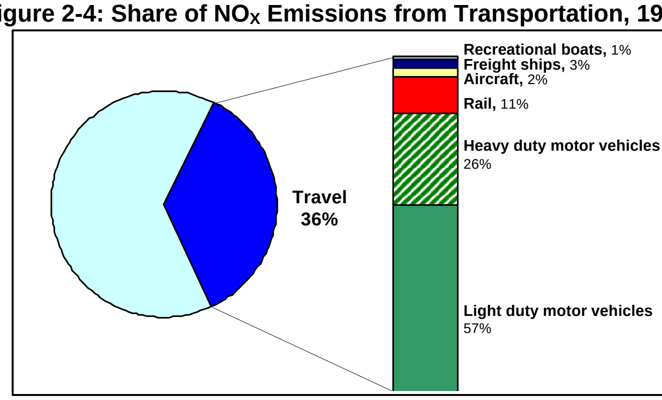
Figure 2-3: Share of VOC Emissions from Transportation, 1997



Source: U.S. Environmental Protection Agency. *National Air Pollutant Emission Trends, 1900-1997.*

Ozone is formed in the atmosphere through the reaction of volatile organic compounds (VOCs) and oxides of nitrogen (NO_X) in the presence of heat and sunlight. Ozone and these precursor pollutants can be transported by prevailing weather patterns to an area hundreds of miles away from pollution sources.

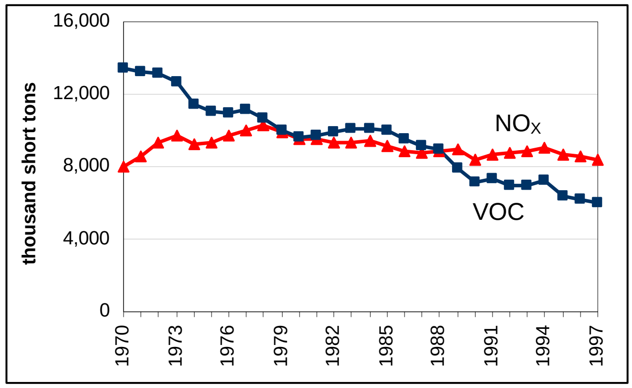
Figure 2-4: Share of NO_X Emissions from Transportation, 1997



Source: U.S. Environmental Protection Agency. *National Air Pollutant Emission Trends, 1900-1997.*

Transportation is a major source of the volatile organic compounds and oxides of nitrogen that contribute to ozone formation. Transportation sources emitted 31 percent of VOCs and 36 percent of NO_X in 1997, as shown in Figures 2-3 and 2-4. VOCs are emitted both from fuel combustion and fuel evaporation. Service stations and solvent use in vehicle manufacturing and refinishing also emitted significant amounts of VOCs. Diesel vehicles emit NO_X at much higher rates than gasoline vehicles; as a result, heavy-duty motor vehicles and rail are much larger contributors to NO_X emissions than to emissions of VOCs.

Figure 2-5: VOC and NO_X Emissions from Travel, 1970-1997



Source: U.S. Environmental Protection Agency. *National Air Pollutant Emission Trends, 1900-1997.*

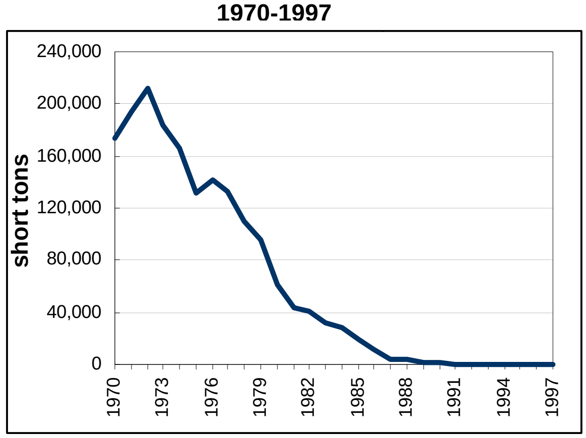
Significant progress has been made in reducing VOC emissions from transportation, and VOC emissions from transportation sources have dropped 56 percent between 1970 and 1997, in comparison to a 24 percent reduction from non-transportation sources. Most of the tonnage reduction has come from light-duty motor vehicles.

In contrast, NO_X emissions have proven more difficult to control. Nationally, NO_X emissions increased by about 11 percent between 1970 and 1997. NO_X emissions from transportation increased 5 percent over this time period. Most of the increase in NO_X from transportation came from non-road sources, like rail, aviation, and maritime transport. NO_X emissions from motor vehicles actually dropped 5 percent between 1970 and 1997, despite a 127 percent increase in vehicle miles traveled.

Lead

In the early 1970s, automobiles were the major contributors of lead (Pb) emissions to the atmosphere. As a result of EPA's regulatory efforts to remove lead from gasoline, transportation sector emissions of lead have declined dramatically, leading to the virtual elimination of lead as an ambient air quality problem. Concentrations of lead in the air decreased by 97 percent between 1978 and 1997, with total emissions of lead down 98 percent between 1970 and 1997.

Figure 2-6: Lead Emissions from Travel, 1970-1997



Source: U.S. Environmental Protection Agency. *National Air Pollutant Emission Trends, 1900-1997.*

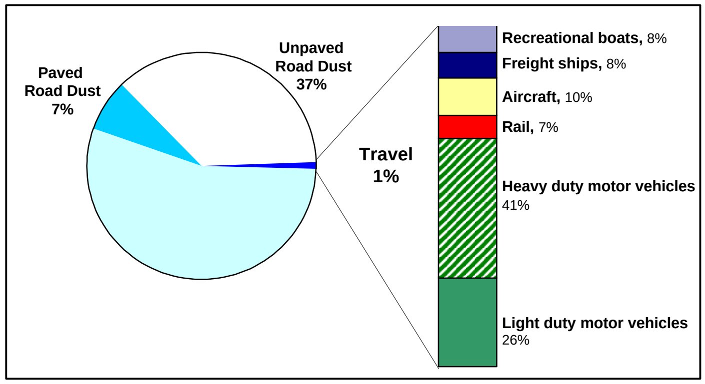
Today, metals processing is the major source of lead emissions and the highest ambient air concentrations of lead are found near ferrous and nonferrous smelters, battery manufacturers, and other stationary sources. Aviation is now the only major source of lead emissions from the transportation sector. Because industrial processes are now responsible for all violations of the lead standard, EPA's lead monitoring now focuses on these point sources.

Particulate Matter

Particulate matter is the term used to describe a mixture of solid particles and liquid droplets found in the air. These particles vary widely in size and can remain suspended in the air for extended periods. EPA has established a National Ambient Air Quality Standard (NAAQS) for both coarse particles under 10 microns in diameter (PM_{10}) and fine particles under 2.5 microns in diameter ($PM_{2.5}$). Fine particles are thought to be most harmful to human health because their small size allows them to penetrate the lungs, resulting in decreased lung function, increased respiratory symptoms and disease, and premature death. PM is also the major cause of reduced visibility in parts of the U.S., and can adversely affect plants, animals, and materials. PM can be emitted directly or formed in the atmosphere as a result of reactions of SO_X, NO_X, and other gases.

Most particulate matter emissions come from sources that are not traditionally inventoried, such as wind erosion, fugitive dust from paved and unpaved roads, and agriculture. Travel contributes more toward fine PM ($PM_{2.5}$) than to PM_{10}, but still makes up just about 4 percent of $PM_{2.5}$ emissions nationally, as shown in Figures 2-7 and 2-8.

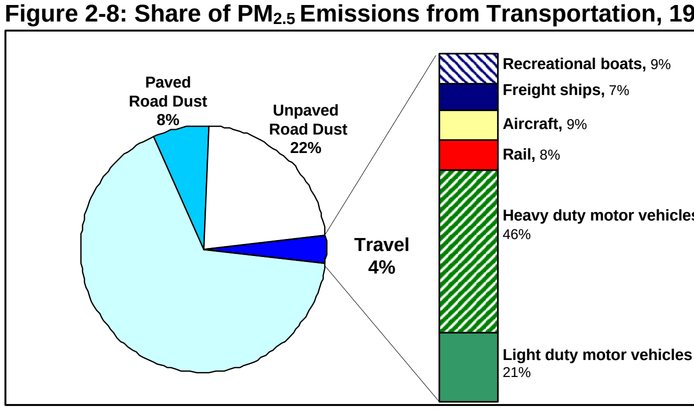
Figure 2-7: Share of PM_{10} Emissions from Transportation, 1997



Source: U.S. Environmental Protection Agency. *National Air Pollutant Emission Trends, 1900-1997.*

Particulate matter emissions tend to be associated most with diesel engines, so heavy-duty motor vehicles are the largest source of transportation-related PM emissions. In contrast to their share of most other pollutants, light-duty motor vehicles make up a relatively small portion of transportation emissions.

Figure 2-8: Share of $PM_{2.5}$ Emissions from Transportation, 1997



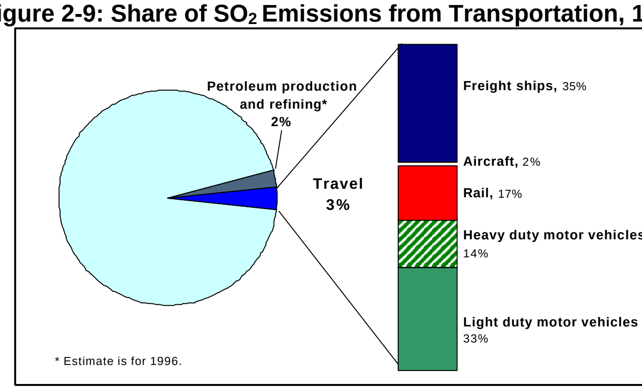
Source: U.S. Environmental Protection Agency. *National Air Pollutant Emission Trends, 1900-1997.*

Direct emissions of PM_{10} from the transportation sector declined by 26% between 1970 and 1997. Emissions from non-transportation sources have fallen due to controls on industrial sources and construction activities, as well as measures to reduce street dust emissions, including the use of clean anti-skid materials like washed sand, better control of the amount of material used, and removal of material from roads as soon as ice and snow melt.

Sulfur Dioxide

Sulfur dioxide (SO_2) is a less pervasive air quality problem nationwide compared to carbon monoxide, ozone, and particulate matter. Over the period 1978 to 1997, concentrations of SO_2 in the air declined by 55 percent. Fewer than 100,000 Americans lived in counties with air quality concentrations above the level of the SO_2 NAAQS in 1997. Despite the small number of exceedances of the SO_2 standard, sulfur dioxide emissions remains an environmental problem. SO_2 contributes to particulate matter in the atmosphere and acid rain.

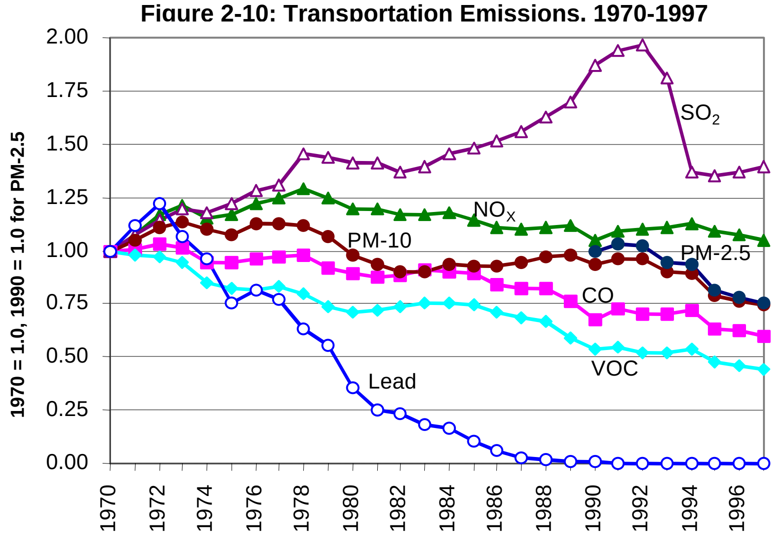
Figure 2-9: Share of SO_2 Emissions from Transportation, 1997



Source: U.S. Environmental Protection Agency. *National Air Pollutant Emission Trends, 1900-1997* and *NET Viewer.*

Transportation is a relatively minor source of SO_2 emissions, contributing about 3 percent of total SO_2 emissions nationwide. Production and refining of petroleum for transportation also contributes about 2 percent of national SO_2 emissions.[4] SO_2 is formed when fuel containing sulfur — mainly coal and oil — is burned and during metal smelting and other industrial processes. The highest monitored concentrations of SO_2 are recorded in the vicinity of large industrial facilities. In contrast to industrial sources, SO_2 emissions from transportation have trended upward through the 1970s and 1980s, largely due to increases in emissions by ships and boats. A substantial decline in heavy-duty vehicle emissions occurred, however, between 1992 to 1994. EPA recently promulgated a new rule that requires significantly lower sulfur content for gasoline, which in turn will help to reduce motor vehicles emissions of VOCs, CO, and NO_X since sulfur in gasoline inhibits the performance of the catalyst on advanced technology vehicles.

Figure 2-10: Transportation Emissions, 1970-1997



Source: U.S. Environmental Protection Agency. *National Air Pollutant Emission Trends, 1900-1997.*

Comparative Trends

Trends in transportation emissions, 1970-1997, are shown in Figure 2-10. As described above, there has been significant progress in reducing transportation emissions of air pollutants since the early 1970s.

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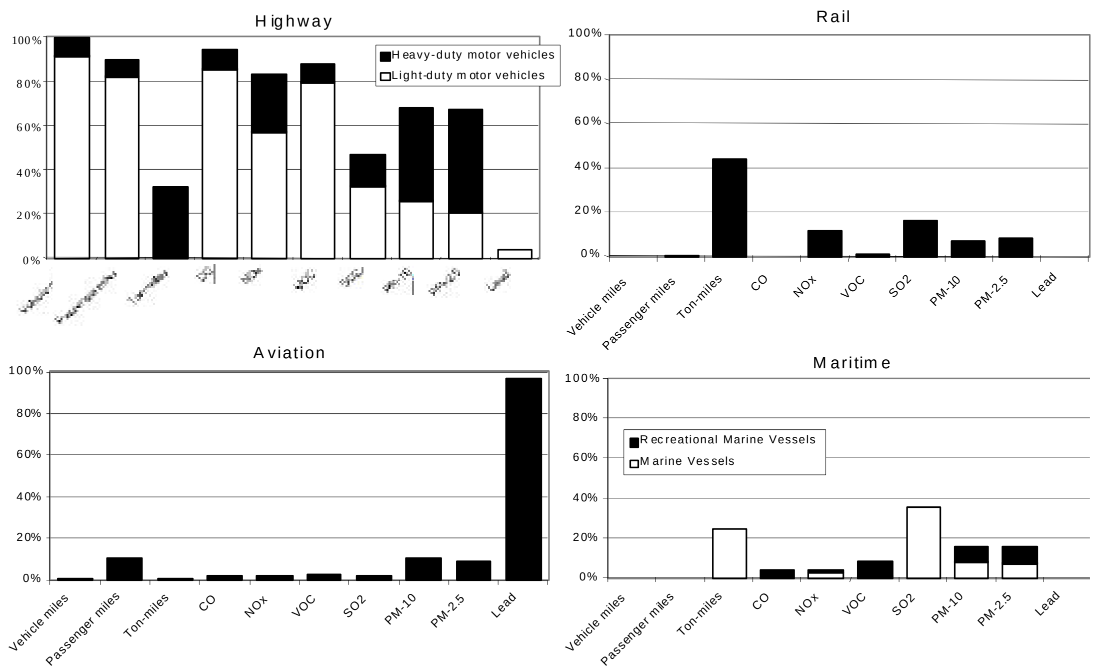
[4] Petroleum production and refining emissions were estimated based on SIC codes 1311 (Crude Petroleum and Natural Gas), 1381 (Drilling Oil and Gas Wells), 1382 (Oil and Gas Field Exploration Services), 1389 (Oil and Gas Field Services, NEC), and 2911 (Petroleum Refining) (Source: U.S. Environmental Protection Agency. *NET Viewer*). This figure was then multiplied by 66.2%, the percent of petroleum used for transportation (Source: U.S. Department of Energy. *Transportation Energy Data Book: Edition 18*).

Transportation emissions have decreased substantially for three of the major pollutants emitted by transportation sources: CO, VOC, and lead. Transportation-related emissions of NO_X have risen slightly, but most of this increase has been from non-road sources. Motor vehicle emissions of NO_x have actually fallen 5 percent between 1970 and 1997, despite a 127 percent increase in vehicle miles traveled.

The contribution of emissions from different transportation sources varies significantly by pollutant, as shown in Figure 2-11. Light-duty on-road vehicles emit the most CO, NO_X, and VOC emissions of any mode of transportation. Light duty vehicles are used for the vast majority of all vehicle miles of travel and passenger miles of travel. Heavy-duty motor vehicles contribute a large portion of particulate matter emissions and NO_X emissions, primarily because diesel vehicles emit a much more of these pollutants than gasoline vehicles. Marine vessels are a major source of sulfur dioxide. Aircraft are the main source of lead emissions from transportation since the phase-out of leaded gasoline.

Figure 2-11: Travel and Criteria Pollutant Emissions by Mode of Travel, 1997



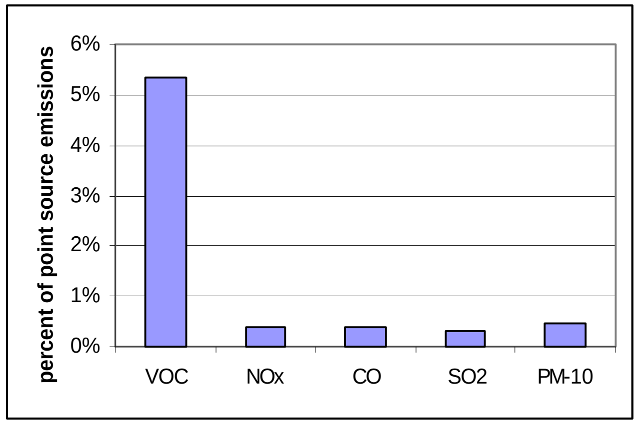
Source: Vehicle miles, passenger miles, ton-miles — U.S. Department of Transportation, Bureau of Transportation Statistics. *National Transportation Statistics 1998.* Emissions — U.S. Environmental Protection Agency. *National Air Pollutant Emission Trends, 1900-1997.* Travel Statistics are for 1996 and emissions estimates are for 1997. Vehicle miles and passenger miles do include recreational marine vessels. Ton miles figure is for domestic freight and assumes all on road transport is by heavy duty vehicles.

EMISSIONS FROM VEHICLE MANUFACTURE, MAINTENANCE, AND SUPPORT

In addition to emissions from travel, criteria pollutant emissions are released from transportation-related activities, including vehicle manufacture and maintenance and support operations. These activities release a very small portion of total criteria pollutant emissions with the exception of VOCs, as shown in Figure 2-12.

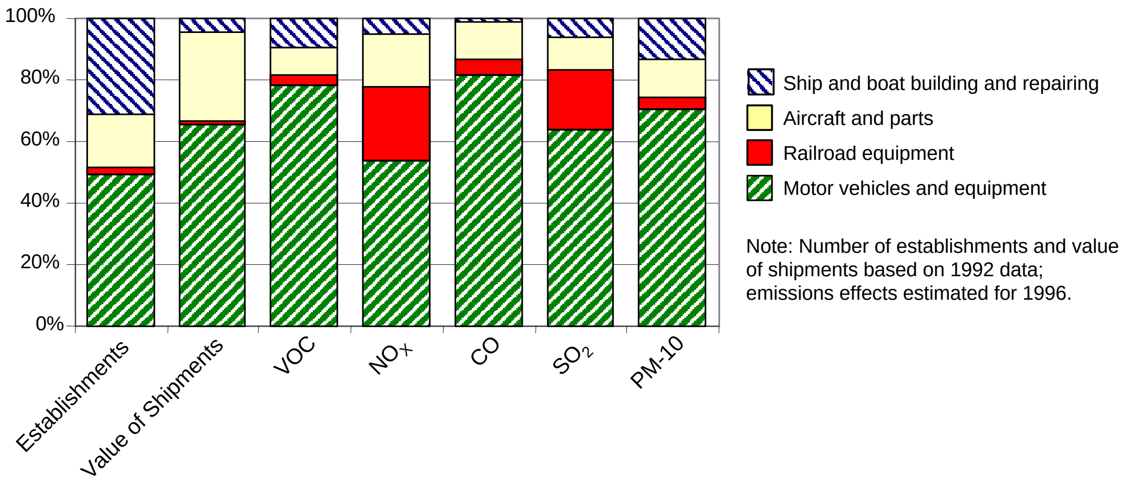
Figure 2-13 compares the contribution of different types of transportation manufacturing facilities to air pollutant emissions and to the number of establishments and value of shipments by industry. The motor vehicle and equipment manufacturing industry is by far the largest transportation-related manufacturing industry, and is responsible for about half of all transportation manufacturing establishments and two-thirds of the value of shipments. It is also responsible for the majority of emissions from transportation-related manufacturing industries. Criteria pollutants are also released from aviation ground support equipment and in the maintenance and support of the transportation system.

Figure 2-12: Percent of Point Source Emissions from Transportation Vehicle and Equipment Manufacturing, 1996



Source: U.S. Environmental Protection Agency. *NET Viewer.*

Figure 2-13: Criteria Pollutant Emissions from Transportation Vehicle and Equipment Manufacturing, 1996

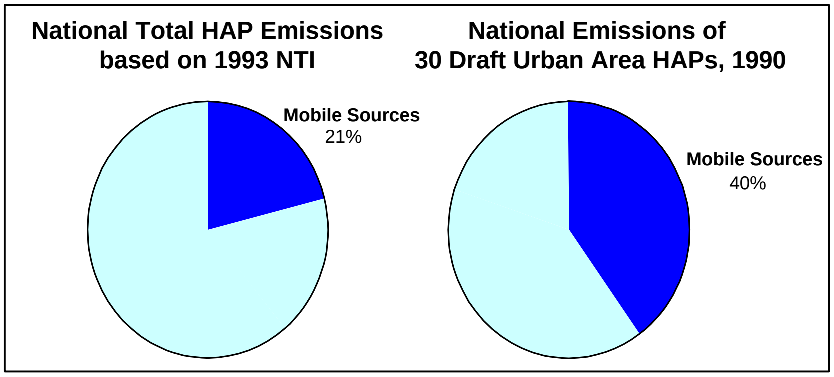


Sources: Establishments and Value of Shipments — U.S. Bureau of the Census. *1992 Census of Manufacturers.* Emissions — U.S. Environmental Protection Agency. *NET Viewer.*

2.2 TOXICS

Hazardous air pollutants (HAPs), commonly referred to as air toxics or toxic air pollutants, are known or suspected to cause cancer or other serious human health effects or ecosystem damage. Section 112 of the Clean Air Act now lists 188 pollutants or chemical groups as hazardous air pollutants and targets sources emitting them for regulation. Compared to the criteria pollutants, less information is available concerning potential health and environmental effects of HAPs. Toxic air pollutants are known, however, to have a variety of environmental effects, including the potential for some HAPs to damage aquatic ecosystems.

Figure 2-14: Mobile Source Contribution to HAP Inventories



Source: U.S. Environmental Protection Agency. *National Air Quality and Emissions Trends Report, 1997.* pp. 69-79.

According to EPA's 1993 National Toxics Inventory (NTI), mobile sources released approximately 21 percent of hazardous air pollutants out of 8.1 million tons of air toxics released nationwide. Recognizing that not all toxics are national problems, EPA has also compiled an interim 1990 emission inventory for 30 proposed urban HAPs associated with area sources. Of these HAPs that pose the greatest threat to public health in urban areas, about 40 percent of emissions came from mobile sources. Urban areas tend to have a higher proportion of emissions coming from mobile sources than rural areas.

Toxics are also released from manufacturing facilities and are reported in the EPA's Toxic Release Inventory (TRI). The transportation equipment industry (SIC Code 37) represents a small share of TRI reported waste in comparison to its scope in the U.S. economy. In 1996, the transportation equipment industry was responsible for 1.6 percent of waste but encompassed 8.5 percent of employment and 12.5 percent of the value of shipments among the industries reporting to TRI.[5]

Over time, chemicals have been added to the TRI, deleted, or redefined. To enable comparison between years, the Table 2-1 reports releases of chemicals required to be reported in all years, called "core" chemicals.

[5] U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics. *1996 Toxics Release Inventory Public Data Release – 10 Years of Right-to-Know: Industry Sector Analyses.* December 1998 (Table 1-5).

Table 2-1: Core Toxic Chemicals Released from Transportation Manufacturing Facilities (Subset of TRI Inventory) in thousands of pounds, 1988-1996[6]

Year	On-road vehicle & equipment manufacturing (SIC 371, 375, 3792)	Rail equipment manufacturing (SIC 374)	Aircraft manufacturing (SIC 372)	Ship- and boat-building and repair (SIC 373)	Total Transportation
1988	116,724	2,210	40,270	17,966	174,960
1994	85,151	1,906	11,297	13,826	110,274
1995	75,855	1,561	9,577	14,869	100,301
1996	68,150	1,425	7,181	14,149	89,480

Source: U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics. *1996 Toxics Release Inventory Public Data Release – 10 Years of Right-to-Know: Industry Sector Analyses.* December 1998 (Table 14-3).

The majority of transportation industry toxic releases come from facilities involved in manufacturing motor vehicles and car bodies (SIC code 3711) and motor vehicle parts and accessories (SIC code 3714). Toxic chemicals may be released to the environment as air emissions, surface water discharges, underground injection, or on-site land releases. The vast majority of releases from transportation-related manufacture were releases to air, which include stack emissions, equipment leaks, evaporative losses, and releases from building ventilation systems.

Overall, the quantity of core toxic chemicals released from transportation-related manufacturing facilities declined by over 50 percent between 1988 and 1996. On- and off-site releases of core chemicals decreased from nearly 175 million pounds in 1988 to 89.5 million pounds in 1996. Reductions in releases were due in part to source reduction, on-site waste management, and tranfers off-site for waste management. One-fifth of firms submitting forms to TRI in the transportation equipment sector (SIC Code 37) reported undertaking one or more source reduction activities during 1996. Good operating practices and raw material and process modifications were the two source reduction activities cited most often by the motor vehicles and car bodies industry (SIC 3711) and the motor vehicle parts and accessories industry (3714) — the two largest sources of waste. Aviation and motor vehicle industries had the highest percentage of waste undergoing either on-site or off-site waste management. In 1996, within all transportation manufacturing industries about 54 percent of toxics were recycled (chemicals were recovered and made available for further use). Another 4 percent were used for energy recovery (combusted to generate heat or energy) and 13 percent were destroyed through treatment.[7]

2.3 GREENHOUSE GASES

Greenhouse gases trap heat within the earth's atmosphere. While most greenhouse gases occur naturally and serve to keep the planet hospitable to life, increasing concentrations of greenhouse gases in the atmosphere threaten to alter the earth's climate dramatically. The world's most respected scientists agree that the threat of global climate change is real and that potential impacts

[6] The transportation manufacturing industry, as defined in this report, excludes a portion of the industries that fall under SIC code 37 (Transportation Equipment). It excludes the following SIC codes: 3761 (Guided Missiles & Space Vehicles), 3764 (Space Propulsion Units & Parts), 3769 (Space Vehicle Equipment, nec), 3795 (Tanks & Tank Components), and 3799 (Transportation Equipment, nec).

[7] Calculated based on: U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics. *1996 Toxics Release Inventory Public Data Release – 10 Years of Right-to-Know: Industry Sector Analyses.* December 1998 (Table 14-9).

are significant, including extreme weather conditions, rising sea levels, and damage to agriculture and ecosystems.

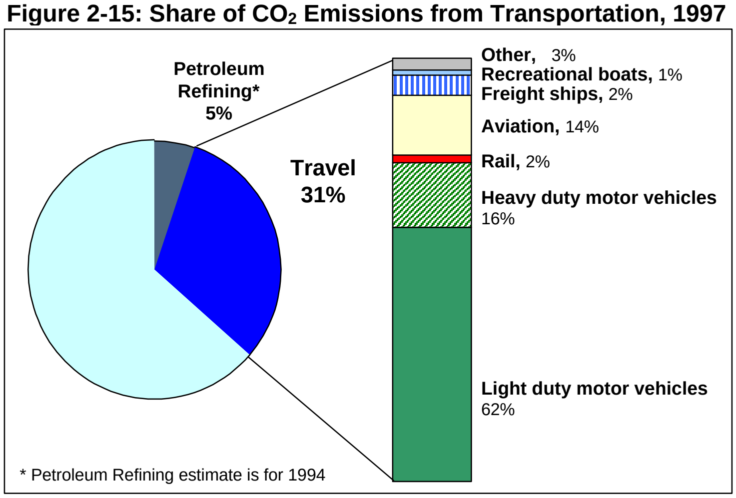
Transportation is a major contributor to emissions of carbon dioxide (CO_2), the most important greenhouse gas. Based on global warming potential, CO_2 accounts for about 84 percent of total greenhouse gas emissions in the U.S. The remainder is made up of methane (9 percent), nitrous oxide (5 percent), halocarbons, and other human-made gases, such as HFCs and PFCs (2 percent).[8] Greenhouse gas emissions from transportation have been rising, in contrast to emissions of other air pollutants, in large part because travel growth has outpaced improvements in transportation energy efficiency. In particular, for motor vehicles — the largest source of carbon dioxide emissions from transportation — vehicle fuel economy has been stagnant over the past few years as more travel has shifted from automobiles to less efficient light trucks, including pick-up trucks, sport utility vehicles, and minivans.

In the following discussion highlighting the percentage of total greenhouse gas emissions from transportation, note that transportation sources are a subset of "mobile sources." As a result, the share of emissions from travel is smaller than the share reported for mobile sources in national greenhouse gas emission inventories compiled by the U.S. Department of Energy and U.S. Environmental Protection Agency.[9]

CARBON DIOXIDE

Transportation sources emitted approximately 31 percent of all carbon dioxide emissions from fossil fuel combustion in the U.S. in 1997. In addition emissions from refining petroleum in the United States for transportation sector use compromised about 5 percent of total emissions. Not accounted for are the emissions associated with extracting crude oil (imports of crude oil made up 42 percent of U.S. petroleum consumption in 1997) and refining oil that is imported as refined petroleum (5 percent of U.S. petroleum consumption in 1997).[10]

Figure 2-15: Share of CO_2 Emissions from Transportation, 1997



U.S. Environmental Protection Agency. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1997.* March 1999 (draft) and U.S. Department of Energy. *Manufacturing Energy Consumption Survey, 1994.*

[8] U.S. Department of Energy, Energy Information Administration. *Emissions of Greenhouse Gases in the United States 1997.* October 1998 (Table ES2).

[9] Transportation sources do not include farm equipment, construction equipment, and utility equipment, which are considered mobile sources. Note that recreational boating is included as a transportation source in this report, even though it is not purely for a transportation purpose.

[10] Percent of emissions from petroleum refining were calculated based on energy data for SIC code 2911 (Source: *Manufacturing Energy Consumption Survey, 1994.*); this figure was then multiplied by 66.2%, the percent of petroleum used for transportation (Source: U.S. Department of Energy. *Transportation Energy Data Book: Edition 18*). Other energy data reported come from U.S. Department of Energy. *Transportation Energy Data Book, 18th. Edition.* Table 1.8.

Transportation sources emitted 460.4 million metric tons of carbon in 1997, out of a total of 1.48 billion metric tons of carbon from fossil fuel combustion.[11] Most transportation emissions come from on-road motor vehicles. About 78 percent of transportation emissions come from on-road vehicles and approximately 14 percent come from aircraft, with the remainder from rail, ships, boats, and other sources. Carbon dioxide emissions from travel have been growing rapidly, in contrast with trends in other air emissions. Transportation emissions increased about 10 percent between 1990 and 1997, growing from 419.1 million metric tons to 460.4 million metric tons of carbon.[12]

In addition to direct release of CO_2 during fossil fuel combustion, CO_2 and other greenhouse gases are released from upstream fuels processing, distribution of fuels, vehicle assembly, and facility maintenance. It is estimated that for gasoline light-duty vehicles CO_2 emissions from feedstock/fuel distribution and production equal approximately 25 to 30 percent of the amount of CO_2 emitted from the vehicle, as shown in Table 2-2. Car assembly and materials emit another 16 percent of the amount emitted from the vehicle. In total, upstream processes emit another 41 to 46 percent of the CO_2 emitted from the vehicle for light-duty gasoline vehicles and about 28 percent of the CO_2 emitted from the vehicle for heavy-duty diesel vehicles.

Table 2-2: Full Fuel Cycle CO_2 -equivalent Emissions for Light-duty Motor Vehicles (grams per mile)

Study	Fuel	Vehicle Use	Feed/Fuel distribution & production	Car assembly & materials	Total Emissions
M.A. Delucchi, Argonne National Laboratory.1991.	Conventional gasoline	344.5	85.9	55.9	486.3
	Reformulated gasoline	333.7	101.6	55.9	491.2
	Diesel fuel	325.0	56.8	42.1	423.9
	Diesel fuel, heavy-duty	2,052.1	369.0	206.0	2,627.1
U.S. Department of Energy. August 1996.	Gasoline	272.4 *	74.9 *	-	347.3 *

*Only includes CO_2 emissions; other estimates are for CO_2 equivalent emissions and consider CO_2, CH_4, N_2O, NO_X, CO, and NMOCs.

Sources: M.A. Delucchi, Argonne National Laboratory. “Emissions of Greenhouse Gases from the Use of Transportation Fuels and Electricity.” ANL/ESD/TM-22, Vol. 1, 1991 (Table 9).U.S. Department of Energy. “Alternatives to Traditional Transportation Fuels 1994. Vol. 2: Greenhouse Gas Emissions.” DOE/EIA-0585(94)/2, August 1996 (Table 7).

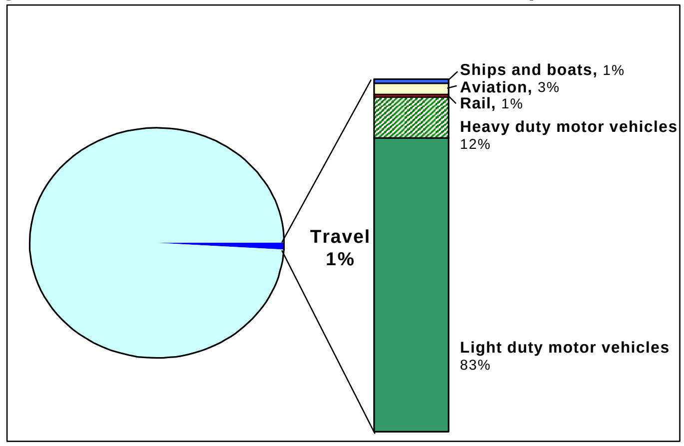
Fossil fuels can also be used for producing products such as plastics, asphalt, or lubricants that store carbon for long periods of time. Asphalt used in road construction, for example, stores carbon. Fossil fuels used in the manufacture of materials like plastics for motor vehicles can also store carbon if the material is not burned.

[11] U.S. Environmental Protection Agency. "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1997." March 1999 (draft).

[12] U.S. Department of Energy, Energy Information Administration. *Emissions of Greenhouse Gases in the United States 1997.* October 1998, Table 10.

METHANE

Figure 2-16: Share of CH_4 Emissions from Transportation, 1997

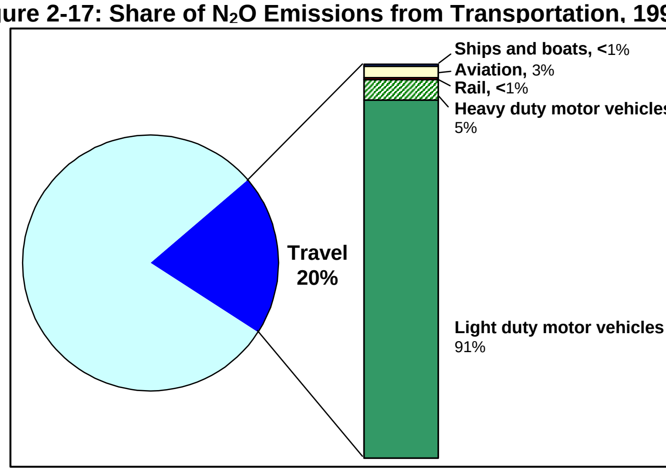


U.S. Environmental Protection Agency. "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1997." March 1999 (draft).

Travel contributes less than one percent of methane (CH_4) emissions nationally, with the majority of emissions coming from landfills and agriculture. Methane emissions from transportation in 1997 were estimated at 234,000 metric tons, down about 11,000 metric tons from 1990 levels. Nearly 95 percent of transportation emissions of methane come from on-road vehicles, with the vast majority of those from light-duty vehicles. Aircraft emit approximately 3 percent of transportation methane emissions, with smaller amounts from locomotives, ships, and boats.

NITROUS OXIDE

Figure 2-17: Share of N_2O Emissions from Transportation, 1997



U.S. Environmental Protection Agency. "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1997." March 1999 (draft).

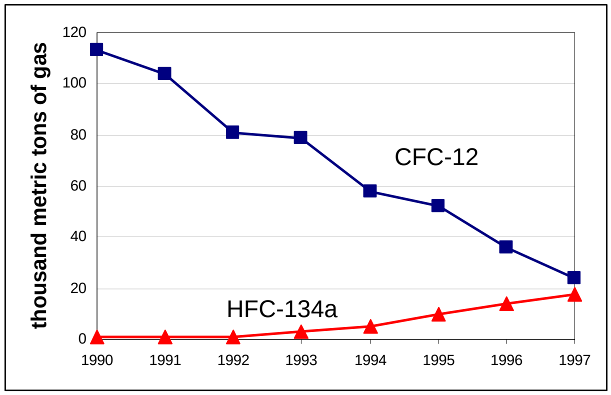
In 1997, travel was the second largest source of nitrous oxide (N_2O) emissions, producing about 20 percent of N_2O emissions in the U.S. Other major sources of N_2O are agricultural soil management and adipic and nitric acid production. Travel was associated with 206,000 metric tons of nitrous oxide in 1997, up nearly 30 percent from the 159,000 metric tons emitted in 1990.

Transportation-related N_2O is a product of the reaction that occurs between nitrogen and oxygen during fossil fuel combustion. Like NO_X emissions, N_2O emissions are closely related to fuel characteristics, air-fuel mixes, and combustion temperatures, as well as use of pollution control equipment. In particular, N_2O can be formed by the catalytic processes used to control NO_X and CO emissions.

2.4 CHLOROFLUOROCARBONS AND STRATOSPHERIC OZONE DEPLETION

Chlorofluorocarbons (CFCs) are human-made derivatives of hydrocarbons. For decades CFC-12 (also known by the trade name Freon) was used as the refrigerant in motor vehicle air conditioning systems. In response to increased scientific understanding of damage to the ozone layer, a worldwide ban on the production of ozone-depleting substances, including CFC-12, has been implemented. Ozone loss in the upper atmosphere is likely to lead to an increase in cataracts and skin cancer, could weaken the human immune system, and can have significant effects on agriculture and plant and animal life. By signing the *Montreal Protocol on Substances that Deplete the Ozone Layer* and *Copenhagen Amendments*, the United States committed to eliminating the production of all CFCs by the end of 1995. On December 31, 1995, CFC-12 production essentially ended in the U.S.

Figure 2-18: Estimated U.S. Emissions of CFC-12 and HFC-134a, 1990-1997



Source: U.S. Department of Energy, Energy Information Administration. *Emissions of Greenhouse Gases in the United States 1997.* October 1998 (Table 31).

It is still legal to use existing stockpiles of CFC-12, but several companies have also developed new substitutes. In order to make sure existing CFC-12 is not released to the atmosphere, EPA issued regulations under the Clean Air Act to require mechanics to recycle CFC-12.

Hydrofluorocarbon HFC-134a became the standard automobile air conditioner refrigerant in 1994, and HFC emissions have been growing as CFCs gradually disappear from the automobile fleet, as shown in Figure 2-18. HFCs, which contain no chlorine, have no effect on stratospheric ozone, but are a greenhouse gas.

2.5 HABITAT AND LAND USE

Development of transportation infrastructure has direct and indirect effects on land use and habitat. Land is used directly for public and private transportation infrastructure, including roads, parking lots, railway terminals, airports, and marine cargo facilities. In addition, the development of these facilities may stimulate changes in land uses, including the development of commercial, residential, and industrial areas, which in turn can reduce or fragment habitat.

LAND USE AND HABITAT FRAGMENTATION

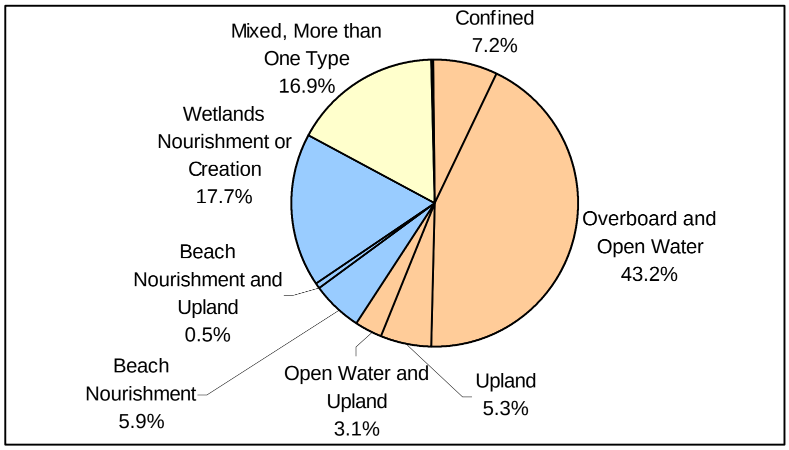
Use of land for transportation infrastructure can adversely impact sensitive ecological resources such as endangered plant and animal species. It can also have more significant impacts through fragmentation of habitats and secondary development. While all forms of transportation infrastructure can adversely affect wildlife and habitat, highways and roads tend to be viewed as the most significant cause of concern because of their pervasiveness and their linear nature, which can form barriers to wildlife. The linear nature of highways — and railways to a lesser extent because they tend to be narrower — divides wildlife habitat into smaller, more isolated pieces of land that can create barriers between functional areas.

Transportation infrastructure is extensive in the United States and growing. Public roads occupied an estimated 17,345 square miles of land in the United States in 1997, a 2 percent increase over the amount in 1990.[13] Between 1945 and 1997, public road mileage increased by about 19%, from 3.32 million miles to 3.96 million miles. Existing rail mileage is approximately 177,000 miles of track.[14] There were 18,345 airports in the U.S. in 1997, a 21 percent increase since 1980. Although infrastructure is pervasive, national-level information on the cumulative impacts of transportation infrastructure on wildlife and ecological systems is limited. Most transportation-related impacts on wildlife and habitat are studied at the local level.

DREDGING AND IMPACTS TO AQUATIC RESOURCES

Dredging is undertaken to improve navigation for water-borne transportation. Damage to habitat can occur because of disturbance and removal of bottom material and disposal of dredged material. The U.S. Army Corps of Engineers dredges and disposes of about 200 to 300 million cubic yards of material annually from Congressionally-authorized navigation improvement and maintenance projects. In addition, permit applicants (e.g., port authorities, terminal owners, industries, and private individuals) dredge an additional 100 million cubic yards annually from navigation projects (i.e., ports, berths, and marinas).[15]

Figure 2-19: Disposal/Use of Material Dredged by U.S. Army Corps of Engineers, 1998



Source: Army Corps of Engineers, Navigation Data Center. *Dredging Statistics Database*. Information compiled as of January 1999.

Dredged material can be disposed of in open water or on land. Open water disposal can alter bottom habitats, decrease water quality, and adversely affect marine organisms. If not contaminated, dredged material can also be used for beneficial purposes, such as construction, beach nourishment, land creation, wetland creation, and wetland restoration. Each year approximately 60 million cubic yards of dredged material is disposed of in the ocean at designated sites.[16] At least 24 percent of dredged material disposed by the U.S. Army Corps of Engineers in 1998 was used for beneficial purposes (beach nourishment, wetlands nourishment or creation), as shown in Figure 2-19.

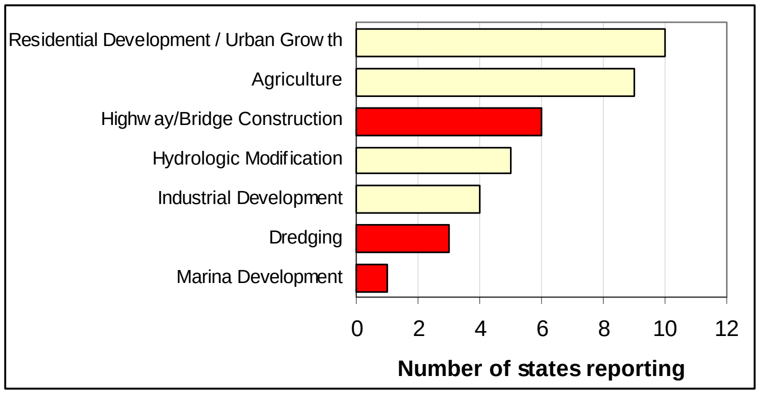
[13] Estimate based on data from U.S. Department of Transportation, Federal Highway Administration. *Highway Statistics 1990, 1995, 1996*, and *1997.* Table HM-60.
[14] Association of American Railroads. www.aar.org, as cited February 14, 1999.
[15] U.S. Environmental Protection Agency. "Ocean Dumping Program Update." EPA842-F-96-003. 1996. http://www.epa.gov/OWOW/OCPD/oceans/update3.html and Army Corps of Engineers, Navigation Data Center. *Dredging Statistics Database*.
[16] U.S. Environmental Protection Agency. "Ocean Dumping Program Update." EPA842-F-96-003. 1996. http://www.epa.gov/OWOW/OCPD/oceans/update3.html

WETLANDS

Wetlands are a specific type of habitat that has received special attention because they perform important ecological functions, including providing habitat for a variety of species and improving water quality by removing nutrients and some contaminants. Highway development has historically been a source of wetland losses, as has dredging for waterway projects.[17]

Of the 12 states providing information about wetland losses in 1996 305(b) reports, 6 states reported wetland losses due to highway or bridge construction, 3 states reported losses due to dredging, and 1 state reported losses due to marina development, as shown in Figure 2-20. Of the 8 states that reported sources of degraded wetland integrity, 3 reported that road construction was a cause. Currently, most states are not equipped to report on the integrity of their wetlands and national trends cannot be drawn from this limited information.

Figure 2-20: Sources of Recent Wetland Loss



Source: U.S. Environmental Protection Agency, Office of Water. *National Water Quality Inventory: 1996 Report to Congress.* April 1998.

Although adverse impacts on wetlands may be unavoidable for some projects, compensatory mitigation efforts are now undertaken to mitigate for unavoidable wetland losses. Mitigation banking is a mitigation technique in which wetland losses are offset by efforts to restore or create other wetlands of comparable value. For the most recent fiscal years, the ratio of wetland creation to wetland loss from the Federal Aid Highway Program has been greater than 2.2:1. In the fiscal years 1996 to 1998, about 10,815 acres of wetlands were created in response to 4,537 acres lost due to the Federal Aid Highway Program, for a net increase of 6,278 acres.[18] There is some debate about the effectiveness of wetland mitigation options in terms of wetland function.

WILDLIFE COLLISIONS

Collisions between vehicles and wildlife can impact certain wildlife populations. Collisions, however, are more frequently regarded as a safety concern because they can lead to vehicle damage and loss of human life. Collisions between transportation vehicles and wildlife can occur with all modes of transportation: motor vehicles, trains, aircraft, and maritime vessels and recreational boats.

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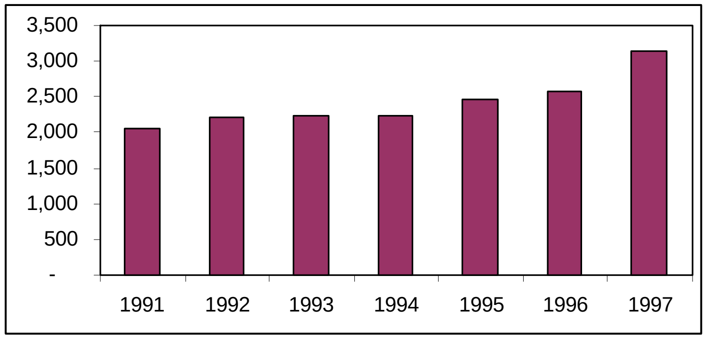
[17] U.S. Environmental Protection Agency. *Appendixes from the National Water Quality Inventory: 1996 Report to Congress.* http://www.epa.gov/OW/resources/9698/appendix.xls

[18] U.S. Department of Transportation, Federal Highway Administration. "Wetlands No-Net-Loss Summary Data." 1998.

There is incomplete data on the extent to which animals are killed by collisions with transportation vehicles and vessels nationwide. The most complete data are for bird and other wildlife strikes with aircraft, which have been monitored by the Federal Aviation Administration since 1965. Quantitative analyses from 1991 to 1997 show an increasing number of collisions over time, as shown in Figure 2-21. Birds were involved in 97 percent of all strikes. As development patterns have disrupted migratory patterns of birds, some airports have become major bird flocking areas due to the sufficient amount of open space.

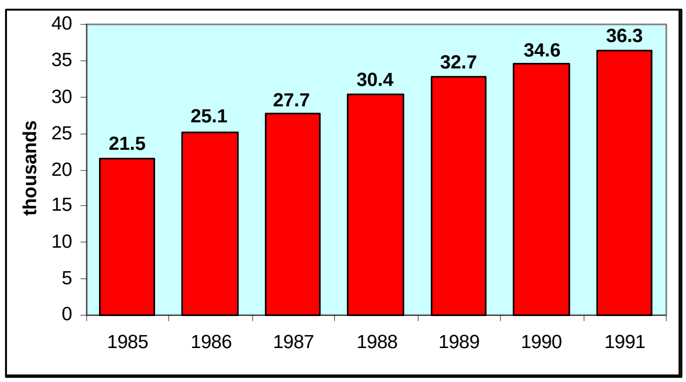
Figure 2-21: Number of Reported Strikes between Wildlife and Civil Aircraft



Source: U.S. Department of Transportation, Federal Aviation Administration. *Wildlife Strikes to Civil Aircraft in the United States 1991-1997*. September 1998.

Data on collisions between animals and motor vehicles is less complete, but also shows a trend of increasing animal-vehicle collisions. The Highway Safety Information System (HSIS) reports on motor vehicle crashes in five states — Illinois, Maine, Minnesota, Utah, and Michigan — for 1985 to 1990 revealed a total of approximately 208,300 animal crashes over this period. Although some crashes involved domestic animals, Michigan's crash report indicated whether the crash was deer related. For Michigan, almost all the hit-animal crashes (99.7 percent) were deer related, and recent data from Minnesota indicate that over 90 percent of animal crashes involved deer. Data from the five states shows a 69 percent increase in animal collisions with motor vehicles over the period 1985 to 1991.

Figure 2-22: Number of Animal Collisions with Motor Vehicles reported to HSIS



Source: U.S. Department of Transportation, Federal Highway Administration, Turner-Fairbank Highway Research Center. "HSIS Summary Reports: Investigation of Crashes with Animals." March 1995 (FHWA-RD-94-156). http://tfhrc.gov/hsis/94-156.htm

INTRODUCTION OF NON-NATIVE SPECIES

Introduction of non-native species, such as non-native grasses and vegetation, can be a significant problem with adverse consequences on habitat and ecosystems. Non-native species may compete with native species for food and force out existing creatures.

Ships are known to be a source of introduction of non-native species to bodies of water. Although national data are not available on damages to ecosystems or species loss due to introduction of non-native species via ship, impacts in specific bodies of water have been identified. For example, over 130 non-native species have been introduced to the Great Lakes since 1800, and nearly a third are believed to have been carried in by ships.[19] Highway maintenance has also been a source of introduction of non-native species of grasses and vegetation. Highway right-of-way has in many instances been planted with non-native grasses, which have spread and forced out native vegetation from the area around highways.

2.6 WATER QUALITY AND AQUATIC RESOURCES

Transportation affects water quality in four ways: 1) the creation of impervious surfaces can adversely affect water quality due to faster rates of runoff, lower groundwater recharge rates, and increased erosion; 2) pollutants such as vehicle exhaust, oil, and dirt, and deicing chemicals, are deposited to roadways and other impervious surfaces; 3) leaking underground storage tanks release petroleum to groundwater; and 4) in the maritime sector, oil spills affect the water quality of inland waterways and coastal areas.

IMPERVIOUS SURFACES

The construction of surface transportation facilities creates impervious surfaces which can harm water quality in a number of ways including:

1. Runoff from roadways, runways, and parking lots can produce increased pollutant loadings to wetlands and streams unless the runoff is treated.

2. An increase in the amount of impervious surfaces results in lower recharge rates for groundwater.

3. Construction of surface transportation facilities contributes to increased erosion, which also occurs as a result of increased runoff from impervious surfaces.

Impervious surfaces are associated with all modes of transportation, but are most extensive for the highway system and airports. The growth in road mileage in the United States has been relatively slow, increasing by 19 percent from 1945 to 1997. Lane mileage in the United States has grown faster, from an estimated 2,693,604 miles in 1984 to 3,968,813 miles in 1997: a 47 percent increase.[20]

Traffic levels are much higher in urban areas than in rural locations; thus, pollutant levels from highway runoff are higher in urban areas than rural areas. Runoff pollution includes particulates and heavy metals from vehicle exhaust fumes, copper from brake pads, tire and asphalt wear deposits, and drips of oil, grease, antifreeze, hydraulic fluids, and cleaning agents.

In the aviation sector, national data on the amount of land area covered by airport runways and facilities is not readily available, although the amount is believed to be quite large. The number of airports with paved runways increased by more than 60 percent between 1980 and 1997, from just under 5,000 to over 8,000.

[19] Council on Environmental Quality. *Environmental Quality 1993.*
[20] Includes all nonlocal lane mileage from Table HM-60 in *Highway Statistics* 1984 and 1997.

RELEASES OF DEICING CHEMICALS, CLEANING FLUIDS, AND WASTEWATER

Use of deicing chemicals facilitates travel during winter weather conditions, and is particularly important for highways and airports. Rock salt is the principal deicing agent used in winter road maintenance throughout the nation. Environmental impacts of road salt include adverse effects to roadside vegetation, harm to soil structure, and potential impacts on drinking water and aquatic life. The actual amount of salt applied to roads nationally is not known, but statistics on road salt sales are available. Approximately 16 million tons of highway salt were sold in 1997.[21]

Aircraft deicers and anti-icers used in North America are based on glycols such as ethylene glycol, diethylene glycol, and propylene glycol, while runway and taxiway deicers are typically formulated with a combination of urea, glycols, sodium formate, and/or potassium acetate. Glycols are biodegradable but can reduce the oxygen available to aquatic life in waters to which deicing and anti-icing fluids are released. Urea degrades to ammonia and nitrate, which are toxic and can contaminate drinking water. It is estimated that 11.5 million gallons of deicing products are used annually in aviation.[22]

Wastewater is another water quality issue associated with transportation. Facilities such as gas stations, maintenance shops, service stations, and freight terminals impact water quality through runoff of gas, oil, and dirt; spills during refueling; waste releases to sewer systems; and cleaning of freight tank interiors. Truck, railcar, and ship cargo interiors that carry fluids must be washed, resulting in the output of spent cleaning fluids, water treatment system sludge, and tank residues.

RELEASES FROM LEAKING UNDERGROUND STORAGE TANKS

Underground storage tanks (USTs) are used to store fuel at gas stations and other facilities, as well as other chemicals. Leaking petroleum USTs can be a source of groundwater contamination. Releases from tanks and piping occur from corrosion of older, unprotected steel tanks and piping, or from cracks in tanks made from other materials. The UST regulations that EPA issued in 1988 established a number of corrective action requirements for UST owners and operators, including the requirement to clean up soil and groundwater as needed to protect human health and the environment. EPA regulations required that by 1998 all existing USTs have spill protection through catchment basins, automatic shutoff devices, overfill alarms, and mandatory corrosion protection for steel tanks and piping. As a result of these stringent regulations, there has been a decrease in the number of active petroleum USTs in the U.S. as petroleum UST systems have been closed.

Data on number of active tanks and the cumulative number of closed tanks, releases reported, cleanups initiated and completed, and emergency responses are compiled in EPA's Corrective Action Measures reports (formerly called "STARS", Strategic Targeted Activities for Results System), summarized in Table 2-3.

[21] Salt Institute, 1998. http://www.saltinstitute.org/33.html#highways
[22] D'Itri (ed.). *Chemical Deicers and the Environment.* Lewis Publishers. 1992.

Table 2-3: Corrective Action Measures Reports for the Entire U.S., 1996 - 1998

Time Period	# Active Tanks	Tanks Closed*	Confirmed Releases*	Cleanups Initiated*	Cleanups Completed*
1st Half FY 1996	1,093,018	1,043,437	314,720	241,787	141,185
2nd Half FY 1996	1,064,478	1,074,022	317,488	252,615	152,683
1st Half FY 1997	1,031,960	1,111,266	329,940	276,603	162,431
2nd Half FY 1997	969,652	1,150,824	341,773	292,446	178,297
1st Half FY 1998	919,540	1,186,341	358,269	301,842	192,065
2nd Half FY 1998	891,686	1,236,007	371,387	314,965	203,247

*Cumulative

Source: U.S. Environmental Protection Agency, Office of Underground Storage Tanks. "Corrective Actions Measures Archive." http://www.epa.gov/swerust1/cat/camarchv.htm

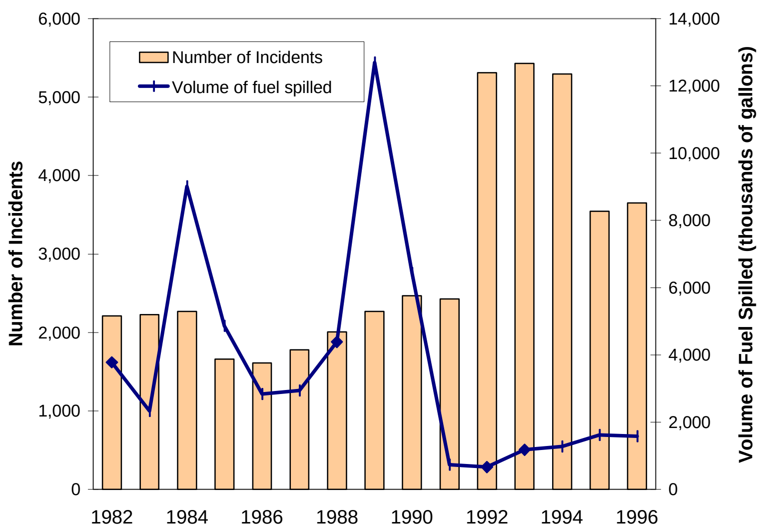
OIL SPILLS AND OTHER RELEASES TO WATER IN THE MARITIME SECTOR

Oil spills during marine transport are the most publicized adverse impact of the maritime industry because of the severe damage to the maritime environment they can cause. The discharge of solid wastes and sewage by maritime vessels can also affect water quality, especially in coastal areas where the volume of traffic is high.

Oil Spills

While the number of incidents in which oil was spilled has increased since 1982, the volume of fuel spilled has actually declined in recent years. Increased safety standards and enforcement resulting in part from the Exxon Valdez spill have led to a dramatic decline in the volume of fuel spilled in recent years.

Figure 2-23: Number of Fuel Spills and Total Volume of Fuel Discharged Annually, 1982-1997



Source: U.S. Department of Transportation, Bureau of Transportation Statistics. *National Transportation Statistics 1998* (Table 4-42).

Dumping of Solid Waste

No information is available on environmental damage caused nationally by dumping of solid waste from ships. It is estimated, however, that the U.S. maritime sector generates over 800,000 metric tons of garbage annually.[23] No information was available on the quantity of this waste that is disposed of at sea as opposed to at port. The most pronounced effects of solid waste dumping are entanglement, ingestion and ghost fishing (when discarded fishing gear continues to catch finfish and shellfish).

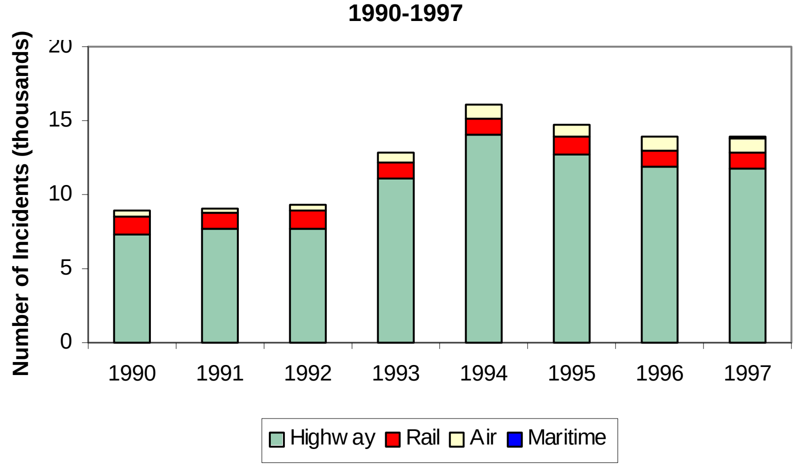
Sewage Dumping

Two major effects of sewage dumping are the introduction of microbial pathogens into the environment and a reduction in dissolved oxygen levels. No nationwide indicators of the environmental impacts of sewage dumping are available. The U.S. Coast Guard estimates that 90 to 95 percent of U.S. commercial vessels and 75 to 80 percent of recreational vessels are equipped with marine sanitation devices.[24] Marinas were reported to be a source of pollution on 3 percent of surveyed miles, with 25 percent of impaired river miles reporting marinas as a source of pollution. This pollution could be from a variety of factors, including sewage, oil spills, and other waste.[25]

2.7 HAZARDOUS MATERIALS INCIDENTS

Hazardous materials are shipped by all modes of transportation, and accidents in all modes that release hazardous materials damage the environment. The number of hazardous materials incidents reported to the Hazardous Materials Incidents System (HMIS) rose from about 8,880 in 1990 to 13,853 in 1997. Most reported incidents occurred in the highway sector, with rail and aviation reporting the next largest number of incidents. Although the number of reported incidents has grown, the incident rate is uncertain. The increase in reported incidents could be due in part to improved reporting or increased economic activity. Ton-miles and vehicle miles of freight increased over the 1990s, but data are not available on the level of shipment of hazardous materials nationally.

Figure 2-24: Number of Hazardous Materials Incidents, 1990-1997



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[23] National Research Council, Marine Board, *Clean Ships, Clean Ports, Clean Oceans: Controlling Garbage and Plastic Wastes at Sea*, National Academy Press, 1995.
[24] U.S. Coast Guard.
[25] U.S. Environmental Protection Agency. *Appendices from the National Water Quality Inventory: 1996 Report to Congress.*

2.8 NOISE

The transportation system is a major source of noise in the United States. Intrusive noise can degrade the quality of life for people in affected areas. In extreme cases, intrusive noise can pose a threat to hearing. Sound is measured on a non-linear scale in units of decibels. An adjusted scale, using A-weighted decibels [dB(A)], emphasizes those sound frequencies that humans hear best. On this scale, a 10-dB(A) increase is perceived as a doubling of sound. Sound above 65 dB(A) is considered annoying and sound above 125 dB(A) is painful. Noise generated from the transportation system generally falls above the annoyance level but below that which is painful. Noise can cause stress and other health problems and can affect the habitat of species living near the roadway.

Recent national data on exposure to noise by different transportation sources are not available. An estimate of the percent of the population exposed to different levels of transportation noise is available for 1980, however, as shown in the following table.

Table 2-4: Percent of U.S. Population Exposed to Different Levels of Transportation Noise, 1980

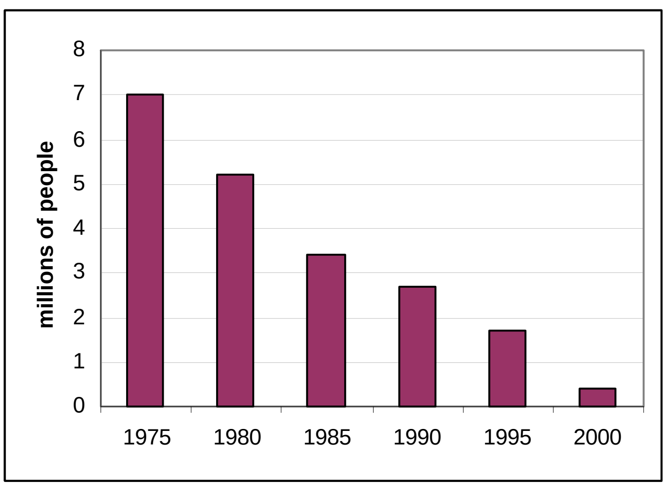
Mode	>55 dB(A) - Annoyance Level	>65 dB(A) - Communication Interference
Highway	37.0%	7.0%
Rail	2.4%	1.0%
Aviation	9.0%	2.0%

Source: Organization for Economic Cooperation and Development (OECD). *Indicators for the Integration of Environmental Concerns into Transport Policies*, OECD Publications, 1993.

Noise levels are site specific and dissipate as the distance from the source increases. Noise is primarily a problem produced by surface transportation and aviation, because of the loud sounds produced by motor vehicles, trains, and aircraft, and their proximity to residential areas.

As shown in Table 2-4, estimates from 1980 suggest that exposure to highway noise is the most significant transportation noise problem in terms of the number of people exposed to high levels of noise, with aviation also a significant problem. Noise from aircraft has been significantly reduced from 1980 levels, however. Noise associated with road transport comes primarily from engine operations, but also includes noise generated from pavement-wheel contact, aerodynamic effects, and the vibration of structures. Typical noise levels for highway vehicles range from about 70dB(A) for freeway traffic to 85 dB(A) for a heavy truck. Noise barrier construction has been used to mitigate this noise exposure, but recent estimates of noise exposure are not available and exposure levels are not known nationally. Noise associated with rail transport comes primarily from engine operations, but also includes rail-wheel contact, aerodynamic effects, and vibration of structures during operations. At the national level, railroad noise is not considered a significant problem, although at the

Figure 2-25: U.S. Population Exposed to DNL of 65dB or Greater from Aircraft



Source: U.S. Department of Transportation, Federal Aviation Administration, *Reprint of Preamble to the Amendments to PART91 Stage 2 Aircraft Phaseout.* 1995.

local level noise impacts from rail may be severe. Typical noise levels are 89dB for an electric locomotive, 93dB for a diesel locomotive, and 120 dB(A) for a locomotive whistle.

Noise is the most recognized environmental impact from aircraft. The U.S. Federal Aviation Administration (FAA) has focused its noise control efforts primarily on regulating aircraft and engines, which has resulted in significant reductions in exposure to aircraft noise. Regulations define three classes of aircraft in terms of their noise levels, with stage 1 being the loudest and stage 3 aircraft being the quietest. All stage 1 aircraft have already been phased out, and the last stage 2 aircraft over 75,000 pounds must be removed from service by December 31, 1999. Other types of controls to reduce aircraft noise exposure include modification of flight paths and timing of aircraft operations (usually to minimize nighttime operations) and soundproofing of buildings subject to the severest noise exposure.

The FAA measures noise through a measurement called the Day-Night Sound Level (DNL) which is also expressed in decibels (dB). Areas subject to a DNL of 65dB or above are considered incompatible with residential uses, but may be compatible with other uses. The population exposed to a DNL of 65dB or higher has been falling over time as Stage 2 aircraft are phased out. It is estimated that by the year 2000, less than 0.5 million people will be exposed to a DNL of over 65dB, down from about 7.0 million people exposed to that sound level in 1975.

2.9 SOLID WASTE

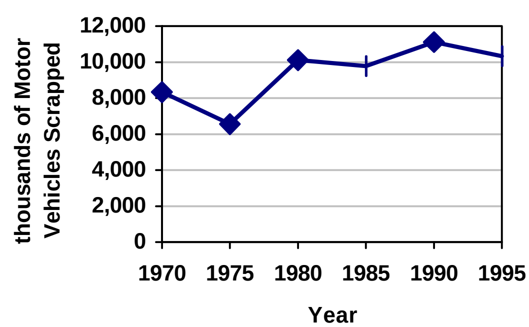
Disposal of parts and vehicles, aircraft, and vessels is the last phase of the life-cycle analysis of the environmental impacts of the transportation sector. National statistics on solid waste generation by the transportation sector are only available for the highway sector. In the maritime sector, most ship disposal (shipbreaking) is done overseas, and in the aviation sector, many older aircraft after are exported.

Motor vehicle dismantling operations generate both solid and fluid waste. Fluids, including motor oil, antifreeze, and air conditioning refrigerants, are recovered to the extent possible and reprocessed or sent to energy recovery facilities. Many vehicle parts, such as radiators and catalytic converters contain valuable metal materials and are usually removed before scrappage for recycling or reuse. In addition, the battery, fuel tank, and tires are also removed before disposal for safety or environmental reasons.

MOTOR VEHICLE SCRAPPAGE

Over 11 million motor vehicles were scrapped in 1996. The number of vehicles scrapped has not grown proportionately with the motor vehicle fleets as the average age of vehicles has grown over time. Figure 2-26 shows the number of vehicles scrapped from 1970-1995.

Figure 2-26 : Number of Motor Vehicles Scrapped Annually (thousands), 1970-1995



Source: U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics 1998*, Table 4-45.

Approximately 75 percent of the material collected from scrapped vehicles (steel, aluminum, copper) is recycled and 25 percent is landfilled. Scrapped vehicle waste comprises about 1.5 percent of total municipal landfill waste.[26]

MOTOR OIL

Used motor oil is an environmental hazard as it contains concentrations of detergents, heavy metals, and other toxics. Improperly disposed motor oil is an extremely concentrated water contaminant . One quart of motor oil can contaminate a million gallons of fresh water. Over 70 percent of motor oil is burned or rerefined. 13.4 percent of used motor oil is illegally dumped and 10.1 percent is landfilled.[27]

TIRES

The characteristics that allow tires to last many thousands of miles on vehicles also make them difficult to dispose of. Many landfills do not allow tire disposal because tires decompose very slowly, collect gases from other garbage, and then gradually float up to the surface of the landfill. Since they retain stagnant water, tires are ideal breeding grounds for mosquitoes. In addition, they contain oil, making them a fire hazard. When ignited, tires emit toxic gases and the use of water to extinguish tire fires can result in soil and water contamination. Tire fires are very difficult to put out, sometimes burning for more than a year. In 1996, some 266 million tires were scrapped, of which 76 percent were recovered.[28] Recovery removes tires from the municipal waste stream through recycling, use as fuel, and exports to other countries. Despite efforts to remove tire dumps, about 800 million tires remain in stockpiles nationwide and represent an ongoing environmental hazard.[29]

BATTERIES

Lead-acid batteries are the largest source of lead entering the waste stream. Close to three-fourths (by weight) of the lead-acid batteries shipped domestically in 1989 were automotive batteries. Improper disposal of lead-acid batteries can cause environmental damage since the average vehicle battery contains 18 pounds of lead, 2 pounds of plastic, and a gallon of acid. The national recycling rate for lead-acid batteries is high, however: about 90 percent are recycled.[30]

RAIL EQUIPMENT, AIRCRAFT, SHIPS AND BOATS, AND PARTS

Solid waste from aircraft and ground support equipment includes batteries, tires, brake pads and other used vehicle components. The main impact of disposal of non-recycled vessel parts is that they contain toxic components (e.g. batteries and engine parts). Estimates of the health and environmental impacts of disposal of rail cars, aircraft, and ships and boats are not available.

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[26] U.S. Environmental Protection Agency, *Profile of the Motor Vehicle Assembly Industry*, EPA Office of Compliance Sector Notebook Project, September 1995.
[27] U.S. Environmental Protection Agency, *Municipal Solid Waste Fact Book – Internet Edition* http://www.epa.gov/epaoswer/non-hw/muncpl/factook/mswf/
[28] Scrap Tire Management Council: http://www.rma.org.
[29] Hilts, Michael. "Broadening the Market for Scrap Tire Rubber." *Solid Waste Technologies*, 10(1):14-19. January/February 1996.
[30] Battery Council International, www.ibstl.com. U.S. Environmental Protection Agency. *Characterization of Municipal Solid Waste in the United States: 1997 Update*. Prepared by Franklin Associates, Ltd. May 1998.

3. HIGHWAY ENVIRONMENTAL INDICATORS

This chapter describes the environmental impacts of highway transportation. Highway transportation is defined here to encompass all forms of on-road motor vehicle transportation including travel and related activities involving personal vehicles, motorcycles, freight trucks, and buses. Agricultural-related mobile sources, like tractors, and off-road recreational vehicles are not included in this discussion. Impacts are described for five categories of highway activities:

- Highway Infrastructure Construction
- Motor Vehicle and Parts Manufacture
- On-road Vehicle Travel
- Maintenance, Support, and Operations
- Disposal of Vehicles and Parts

3.1 HIGHWAY INFRASTRUCTURE CONSTRUCTION

Highway infrastructure projects include construction of new roads, additions to road capacity, and system preservation projects, such as resurfacing and reconstruction. Over the five years, 1993 to 1997, an average of 16,389 miles of Federal-aid roadway improvements were underway each year. On average, 492 miles of new routes (3 percent of project miles) and 2,130 miles of capacity additions (13 percent of project miles) were underway annually, while the remaining miles were system preservation-related projects such as reconstruction and resurfacing.[1] Considerable construction-related activity also occurs on non-Federal-aid highways, which make up over three-fourths of all highway miles.[2]

Highway infrastructure projects can impact natural resources in and around new or existing rights of way. Development of new roads involves taking of developed or undeveloped land for right of way and for "borrow pits" that are used as a source of fill material during construction. Environmental impacts that occur during road construction and widening include erosion, degradation of water quality as a result of excessive runoff during excavation activities, and air pollutant and greenhouse gas emissions from construction equipment.

Longer-term environmental impacts caused by highway infrastructure construction include fragmentation and loss of habitat, and degradation of water quality associated with increases in impermeable road surfaces. Indirectly, road construction contributes to changes in land use patterns, which can have more extensive effects on habitat. Motor vehicle-related infrastructure, such as paved parking lots and driveways, also destroy and fragment habitat. Upstream effects are also associated with the manufacture of asphalt, concrete, steel, and other materials used in highway projects.

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[1] U.S. Department of Transportation, Federal Highway Administration. *Highway Statistics 1997*. November 1, 1998. p. IV-43.

[2] U.S. Department of Transportation, Federal Highway Administration. *Highway Statistics 1997*. November 1, 1998. Table HM-18.

Environmental regulations and environmental management activities by transportation agencies limit the amount environmental damage caused by highway construction. A detailed environmental impact statement (EIS) is usually required prior to project development and impacts on environmental resources such as wetlands or endangered species and their habitats are usually mitigated through project modifications. During construction, erosion impacts are minimized through careful project management, and efforts are now being made to address polluted runoff from highways through stormwater management programs.

LAND USE AND HABITAT DISRUPTION

DESCRIPTION OF IMPACT

Taking of land for a new highway may adversely affect sensitive ecological resources such as endangered plant and animal species or their habitats. Since the annual increase in road mileage is relatively small compared to the existing system, the aggregate national impacts associated with direct loss of habitat to new construction are low. Roads, however, can have a significant impact locally and regionally. Roads can split natural habitats, decreasing habitat necessary to support certain species populations and reducing interaction with other communities. Habitat fragmentation (also affected by the volume of traffic) is known to produce declines in both the number of species (diversity) and their populations (abundance).

Wetlands are a specific type of habitat that has received special attention because they perform important ecological functions. Wetlands support a diverse range of species and provide critical habitat for more than half of all endangered fish and amphibian species in the United States. Wetlands also provide other desirable functions such as flood control, mitigation of damage from erosion, and improvement in water quality by removing excess nutrients and some chemical contaminants. Due to the linear nature of highway projects, many cross watercourses and some may have unavoidable adverse effects on wetlands.

Although significant wetland losses have occurred historically due to highway development and urban development, compensatory mitigation efforts are now undertaken to mitigate for unavoidable wetland loss. The national policy of "no net loss of wetlands" has recently been strengthened with new priorities to produce net increases in wetland acreage resulting from Federal-aid highway projects. Questions still remain, however, about the effectiveness of wetland mitigation approaches in terms of wetland function.

FACTORS THAT AFFECT IMPACT

- Type of construction activity (maintenance v. capacity expansion)
- Ecological conditions/type of land (i.e., wetlands, forest, etc.)
- Species/habitat in and near the right of way
- Type of road surface (paved/unpaved) and barriers to wildlife crossing
- Implementation of various efforts to avoid or mitigate impacts (e.g. wildlife crossings)

INDICATORS OF ENVIRONMENTAL IMPACT

Wetland acreage affected by highways is the only measure of habitat loss associated with road construction that is tracked nationally. Quantified data on other environmental outcomes from highway infrastructure, such as losses of endangered species and habitat fragmentation are not available at a national level. The amount of highway construction and land area occupied by highways provide an indication of environmental impact. These measures, however, are limited because they do not provide information on environmental mitigation practices, the sensitivity of wildlife in a project area, or secondary effects.

WETLANDS LOSSES AND GAINS FROM MITIGATION

The Clean Water Act requires states and other jurisdictions to provide a variety of information on water quality to EPA as part of "305(b)" reports. However, flexibility in the 305(b) reporting requirements means that reporting of wetlands-related impacts due to road construction is not mandated. Only 12 states provided information about wetlands losses in 1996 305(b) reports. Of these states, 6 (50 percent) reported wetlands losses due to highway/bridge construction.[3] Of 8 states reporting sources of degraded wetland integrity, 3 (37 percent) reported that road construction was a cause, while 7 (87 percent) reported urban run-off as a cause. Trend data are unavailable because reporting methodologies vary from year to year.

Source: U.S. EPA, Appendices from the National Water Quality Inventory: 1996 Report to Congress. http://www.epa.gov/OW/resources/9698/appendix.xls

While historically transportation has been a source of net wetland losses, in recent years, the Federal-aid Highway System has been a net contributor to wetland acreage through mitigation projects.

Table 3-1: Wetland Losses and Creation Associated with the Federal Aid Highway Program

Year	Wetland Acres Impacted	Wetland Acres Mitigated	Ratio of Wetlands Created to Wetlands Lost
FY 1996	1,568	3,554	2.3 : 1
FY 1997	1,699	4,483	2.6 : 1
FY 1998	1,270	2,778	2.2 : 1

Source: U.S. Department of Transportation, Federal Highway Administration. "Wetlands No-Net-Loss Summary Data." 1998. Data based on figures reported by FHWA Regional Offices.

LAND OCCUPIED BY HIGHWAYS

In 1997, public roads occupied an estimated 17,345 square miles of land (11.1 million acres), not including road shoulders and medians. This area equals less than 0.5 percent of U.S. land area. It is an increase from 17,013 square miles (10.9 million acres) in 1990.

[3] Other sources included agriculture (9 states), and residential development and urban growth (10 states).

Table 3-2: Land Area Occupied by Roadways, 1990-1997 (Square Miles)

Year	Rural Roads	Urban Roads	Total Public Roads	% Increase from 1990
1990	13,402	3,610	**17,013**	-%
1995	13,278	3,926	**17,205**	1.1%
1996	13,284	3,963	**17,247**	1.4%
1997	13,363	4,012	**17,375**	2.1%

Source: Estimate based on data from U.S. Department of Transportation, Federal Highway Administration. *Highway Statistics 1990, 1995, 1996* and *1997.* Table HM-60.[4]

Rural roads made up approximately 77% of all land used for highways, occupying an area larger than the state of Maryland. Urban roads took up 23% of total land used for highways, occupying an area larger than the state of Delaware.

One study estimated that paved and unpaved public roads (including medians and shoulders) occupy about 25,000 square miles of land; if off-street parking, garages, carports, and driveways are included, the land area increases to 29,000 square miles.

Source: Delucchi, M.A. "Bundled Private Sector Costs of Motor Vehicle Use." Report No. 6 in the Series: *The Annualized Social Costs of Motor Vehicle Use in the U.S., Based on 1990-91 Data.* Davis, CA: University of California, Davis, Institute of Transportation Studies.

LANE MILEAGE

There were approximately 8.24 million lane miles on roadways in the U.S. in 1997. This is an increase of nearly 167,000 lane miles since 1990 — a 2.1 percent increase.

Table 3-3: Lane Miles, 1990-1997

Year	Lane Miles	% Increase from 1990
1990	8,071,708	-%
1995	8,158,181	1.1%
1996	8,177,823	1.3%
1997	8,238,494	2.1%

Source: U.S. Department of Transportation, Federal Highway Administration. *Highway Statistics 1990, 1995, 1996* and *1997.* Table HM-60.

ROAD MILEAGE

Between 1945 and 1997, 638,998 new miles of public roads were added in the United States, a 19 percent increase in road mileage. The most significant increases in road mileage occurred in the 1950s and 1960s. Between 1990 and 1997, road mileage in the United States increased by 91,357 miles, or 2.4 percent.

[4] Values calculated based on number of lane miles times estimated average width per road type: interstate highways - 12 ft., rural other arterials - 11.9 ft., urban other arterials - 11.8 ft., rural collectors - 11 ft., urban collectors - 11.3 ft., local roads - 11 ft.

Table 3-4: Public Road Mileage, 1945 - 1997

Year	Public Road Mileage	% Increase from 1945
1945	3,319,286	-%
1950	3,312,975	0%
1955	3,418,214	3%
1960	3,545,693	7%
1965	3,689,666	11%
1970	3,730,082	12%
1975	3,838,146	16%
1980	3,859,838	16%
1985	3,863,913	16%
1990	3,866,927	16%
1991	3,883,921	17%
1992	3,901,082	18%
1993	3,905,212	18%
1994	3,906,596	18%
1995	3,912,227	18%
1996	3,933,986	19%
1997	3,958,284	19%

Source: U.S. Department of Transportation, Federal Highway Administration. *Highway Statistics Summary to 1995* (Table HM-212), *Highway Statistics 1996* and *1997* (Table HM-12).

HIGHWAY RUNOFF AND WATER QUALITY IMPACTS

DESCRIPTION OF IMPACT

At highway construction sites, run-off, particularly where groundcover is removed, can cause erosion of soil, sedimentation in water bodies, and other changes that disrupt aquatic habitats such as fish-spawning areas and water vegetation. Longer term effects of roadway infrastructure include changes in watershed hydrology. Unpaved roads contribute to sedimentation as soil and gravel run off into stream channels. Impervious road surfaces increase both the volume and rate of surface water runoff and act as a conduit for a wide variety of toxic pollutants. Pavement covers soils and vegetation that would otherwise slow and absorb runoff before it reaches receiving bodies of water, and stormwater systems speed the flow of runoff to sewers. Higher volumes and faster rates of runoff in turn increase sedimentation, nutrients, and acidity of water. High volumes of runoff from hot paved surfaces can also boost surface water temperatures harming fish and other aquatic life.

Average daily traffic (ADT) also has a strong influence on the quality of runoff. Because ADT levels are higher in urban areas than rural locations, pollutant levels in highway runoff are higher in urban areas. Contaminants are deposited on roadway surfaces, median areas, and rights-of-way from atmospheric fallout, vehicle exhaust, lubrication system losses, tire and brake wear, transportation load losses, deicing agents, and paint from infrastructure. During storm events, rainwater washes out atmospheric pollutants and upon surface impact (or snowmelt) it picks up roadway deposits and runs off into receiving water bodies.

Runoff pollutants from vehicles include particulates and heavy metals from exhaust fumes, copper from brake pads, tire and asphalt wear deposits, and drips of oil, grease, antifreeze, hydraulic fluids, and cleaning agents. Indirectly, vehicles also contribute to polluted runoff by carrying solids from parking lots, urban roadways, construction sites, farms, and dirt roads.

FACTORS THAT AFFECT IMPACT

- Paved surface area
- Level of traffic activity
- Rate of deposition of contaminants on road surface per vehicle
- Precipitation activity: antecedent dry period, storm intensity and duration, total amount of rainfall/snowmelt
- Drainage characteristics
- Ecology and other aspects of receiving water bodies: type, size, diversity, potential for dispersion

INDICATORS OF ENVIRONMENTAL IMPACT

Information on water quality is compiled by states, but it is difficult to determine what portion of impaired river miles and lakes are directly affected by highway runoff. As a result, the actual contribution of highways to poor quality of water bodies is unknown. Paved surface area serves as an indicator of runoff impacts because impervious surfaces are associated with higher rates of runoff.

IMPAIRED WATERWAYS IMPACTED BY HIGHWAY RUNOFF AND URBAN RUNOFF

In 1996, of the 693,905 river miles surveyed, urban runoff was estimated to be a leading source of impairment for 13 percent of impaired river miles, up from 11 percent in the 1994 report.

Of the 16.8 million acres of lakes, reservoirs, and ponds surveyed, 417,138 acres were reported to be impaired due to highway maintenance and runoff — 6 percent of impaired lake acres (2 percent of total lake acres surveyed). The proportion of impaired lake acres reported affected by urban runoff decreased from 24 percent to 21 percent between 1994 and 1996, and the number of impaired estuaries affected by urban runoff decreased from 59 percent to 46 percent.

Source: U.S. Environmental Protection Agency. *Appendixes from the National Water Quality Inventory:1996 Report to Congress.* http://www.epa.gov/OW/resources

IMPERVIOUS SURFACES

The exact contribution of transportation to urban runoff is not known, but it is expected to be large, since road surfaces occupy a significant portion of land in urban areas, 19 percent according to Tolley, 1995. While road mileage is not growing quickly, paved mileage is growing more rapidly.[5] While total road mileage increase 19 percent between 1945 and 1997, paved road mileage increased almost threefold (278 percent). The percentage of roads in the U.S. that are paved has increased from about 19% in 1945 to 61% in 1997.

[5] This has implications for increased runoff impacts, but also has other implications, such as reduced particulate emissions from re-entrained dust and perhaps higher speeds of travel and greater emissions per VMT for certain pollutants.

Table 3-5: Unpaved and Paved Public Road Mileage, 1945-97

Year	Unpaved	Paved	% Paved
1945	2,681,316	637,970	19%
1950	2,532,978	779,997	24%
1955	2,422,428	995,786	29%
1960	2,315,224	1,230,469	35%
1965	2,235,066	1,454,600	39%
1970	2,071,661	1,658,421	44%
1975	1,982,786	1,855,360	48%
1980	1,787,145	2,072,692	54%
1985	1,749,855	2,114,057	55%
1990	1,612,104	2,254,822	58%
1991	1,604,317	2,279,603	59%
1992	1,598,345	2,302,736	59%
1993	1,627,525	2,277,686	58%
1994	1,564,416	2,342,179	60%
1995	1,533,958	2,378,268	61%
1996	1,553,913	2,380,072	61%
1997	1,548,349	2,409,935	61%

Sources: U.S. Department of Transportation, Federal Highway Administration. *Highway Statistics Summary to 1995* (Table HM-212), *Highway Statistics 1996* and *Highway Statistics 1997* (Table HM-12).

3.2 MOTOR VEHICLE AND PARTS MANUFACTURE

The motor vehicle and motor vehicle equipment industry is the largest manufacturing industry in North America, accounting for about 4 percent of gross domestic product (GDP).[6] Nearly 6.1 million passenger cars and 5.7 million commercial vehicles were manufactured in the U.S. in 1996.[7] There are approximately 4,467 motor vehicle and equipment facilities in the U.S., 39% of which are in the Great Lakes Region.[8] The massive size of the automotive industry and the diverse nature of parts required to produce a car requires the support of many other major U.S. industries such as the plastics and rubber industry and the electronic components industry.

Facilities involved with the manufacturing of automobiles are located across the U.S. and are organized based on the types of products produced. Businesses involved in the manufacturing of these products range from the large multi-national automakers to small independent automotive parts suppliers.

The many different production processes employed to manufacture a motor vehicle require a vast amount of material input and generate large amounts of waste. The outputs resulting from the various stages of production range from air emissions from foundry operations to wastewater containing spent solvents from surface painting and finishing. For the industry as a whole, solvents such as toluene and acetone comprise the largest number of releases. The large quantity of solvent releases can be attributed to the solvent-intensive finishing processes employed by the industry. In addition to being used to clean equipment and metal parts, solvents are components of many coatings and finishes applied to automobiles during the assembly and painting/finishing operations.

Federal regulatory programs, such as the Clean Air Act and the Resource Conservation and Recovery Act (RCRA) of 1976, which addresses solid and hazardous waste management activities, have helped to reduce the environmental impacts of vehicle equipment manufacture. Voluntary initiatives by the automotive industry to explore pollution prevention opportunities also have reduced environmental impacts.

TOXIC RELEASES

DESCRIPTION OF IMPACT

The manufacture of motor vehicles and equipment results in environmental impacts through the release of toxics to the air, soil, and water. The top five toxic pollutants (by volume) generated by the motor vehicle manufacturing industry include xylene, glycol ethers, toluene, methyl isobutyl ketone, and N-butyl alcohol. These are solvents used to clean equipment and metal parts, and are

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[6] U.S. Department of Commerce, Bureau of Economic Analysis.

[7] U.S. Department of Transportation. *National Transportation Statistics 1998* (Table 1-28). www.bts.gov/btsprod/nts/

[8] U.S. Environmental Protection Agency. *Sector Notebook: Motor Vehicle Assembly Industry.* 1995.

used in many coatings and finishes.[9] The industry has reduced toxic releases considerably in recent years through a mix of voluntary and mandated actions.

The manufacturing process begins with foundries that cast metal products, which are used in the production of motor vehicles and motor vehicle equipment. Foundries create a number of wastes that may pose environmental concerns. Dust is created during sand preparation, molding, and shakeout and is of concern due to the carcinogenic potential of the crystalline silica in the sand. Gases containing lead, cadmium, particulate matter, and sulfur dioxide are created during iron melting. Wastewater generated primarily during slag quenching operations and by wet scrubbers employed as air pollution control devices may contain cadmium and lead.

The next major process in the manufacturing of automotive parts is metal fabrication. Metal fabrication involves the shaping of metal components. Many automotive parts, including fenders, hubcaps, and body parts are manufactured in metal fabricating shops. Each of the metal shaping processes can result in waste metalworking fluids. Metalworking fluids typically become contaminated with extended use and reuse and they may contain constituents of concern, including toxics such as cadmium, chromium, and lead. Many fluids may also contain chemical additives such as chlorine, sulfur and phosphorus compounds, phenols, cresols, and alkalines. In the past, such oils have commonly been mixed with used cleaning fluids and solvents (including chlorinated solvents). Air emissions may result through volatilization during storage, fugitive losses during use, and direct ventilation of fumes.

Following fabrication, metal parts must be finished. Numerous methods are used to finish metal products, and surface preparation operations generate wastes contaminated with solvents and or metals depending on the type of cleaning operation. Concentrated solvent-bearing wastes and air emissions may arise from degreasing operations. Chemical treatment operations can result in wastes that contain metals of concern. Electroplating operations can result in solid and liquid waste streams that contain constituents of concern. Related operations, including all non-painting processes, can contribute wastes including scrap metals, cleaning wastewater, and other solid materials.

Once the various automotive parts are produced, they are ready to be brought together for assembly. Due to advances in technology, well designed operating procedures, and the implementation of strategies to limit waste from assembly, little waste is generated during the actual assembly of an automobile. The final phase of motor vehicle manufacture is painting. Various solid and liquid wastes may be generated throughout painting operations and are usually the result of paint application and drying, cleanup operations, and disposal of leftover and unused paint as well as containers used to hold paints.

FACTORS THAT AFFECT IMPACT

- Number of vehicles built
- Efficiency of controls and efforts to reuse or recycle chemicals, including pollution prevention
- Amount of chemicals transferred to other locations for recycling, energy recovery, or treatment

[9] U.S. Environmental Protection Agency. *Sector Notebook Data Refresh - 1997*. May 1998 (p. T2).

- Types of chemicals released - toxicity
- Exposure to impacts (population in vicinity of manufacturing facility)

INDICATORS OF ENVIRONMENTAL IMPACT

No quantified data on human health impacts, such as increased incidence of cancer from toxics, or habitat and species impacts are available. Estimates of TRI releases are available, however.

TOXIC RELEASES

According to the 1996 Toxic Release Inventory, 728 motor vehicle-related manufacturing facilities (SIC codes 3711, 3713, 3714, 3715, 3716, 3751, and 3792) released nearly 73 million pounds of toxic pollutants to the environment in 1996, as shown in the table below. The largest quantity of toxic chemicals were reported released from industries producing motor vehicles and car bodies (SIC code 3711) and motor vehicle parts and accessories (SIC code 3714).

Table 3-6: Toxic Chemicals Released from Motor Vehicle-Related Manufacturing Facilities, 1996 (pounds per year)

SIC	Industry Type	Total On-Site Releases	Total Off-Site Releases (Transfer to Disposal)	Total Quantity Released to the Environment
3711	Motor Vehicles & Car Bodies	40,587,234	1,517,251	42,104,485
3713	Truck & Bus Bodies	4,770,261	133,698	4,903,959
3714	Motor Vehicle Parts & Accessories	16,080,845	4,348,414	20,429,259
3715	Truck Trailers	1,821,756	16,370	1,838,126
3716	Motor Homes	1,353,532	1,438	1,354,970
3751	Motorcycles, Bicycles, & Parts	721,200	9,050	730,250
3792	Travel Trailers & Campers	1,276,632	49,181	1,325,813
-	TOTAL	**66,611,460**	**6,075,402**	**72,686,862**

Note: On-site releases from Section 5 of Form R. Off-site releases from Section 6 of Form R.

Source: U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics. *1996 Toxics Release Inventory Public Data Release – 10 Years of Right-to-Know: Industry Sector Analyses.* December 1998 (Table 14-3).

Total production-related waste for motor vehicle-related manufacturing totaled 271.3 million pounds of toxic chemicals in 1996. Of the total production-related toxic waste, 12 percent underwent on-site waste-management (either recycling, use for energy recovery, or treatment on-site) and 61 percent was transferred off-site for waste-management. In total, 57 percent of total production-related toxic waste was recycled.

Source: U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics. *1996 Toxics Release Inventory Public Data Release – 10 Years of Right-to-Know: Industry Sector Analyses.* December 1998 (Table 14-9).

Most toxic releases from motor vehicle-related manufacturing facilities were emitted to the air. Because chemicals have been added to the Toxic Release Inventory (TRI), deleted, or redefined over time, the following table reports only releases of "core" chemicals required to be reported in all years, 1988-1996.[10] Releases of core chemicals dropped by 48.56 million pounds — a 42 percent reduction — between 1988 and 1996.

Table 3-7: Toxic Chemicals (Core) Released from Motor Vehicle-Related Manufacturing Facilities (SIC 3711, 3713, 3714, 3715, 3716, 3751, and 3792), 1988-1996 (thousands of pounds per year)

Year	On-site Releases					Off-site	Total
	Air	Water	Under-ground injection	Direct to land	Total On-site Releases	Releases	Releases to the Environment
1988	101,613.4	167.3	1.4	1,731.2	103,513.3	13,211.0	116,724.3
1994	79,145.9	15.1	-	152.8	79,313.7	5,837.5	85,151.3
1995	69,200.0	12.5	-	313.4	69,522.9	6,332.5	75,855.4
1996	62,797.2	20.7	-	541.9	63,359.8	4,790.1	68,149.9

U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics. *1996 Toxics Release Inventory Public Data Release – 10 Years of Right-to-Know: Industry Sector Analyses.* December 1998 (Table 14-14).

CRITERIA AIR POLLUTANTS

DESCRIPTION OF IMPACT

Criteria air pollutants are emitted during various stages of the manufacturing process. Of particular note, volatile organic compounds (VOC) result from the painting and finishing application processes (paint storage, mixing, applications, and drying) as well as cleaning operations. These emissions are composed mainly of organic solvents that are used as carriers for the paint. Solvents are also used during cleanup processes to clean spray equipment between color changes, and to clean portions of the spray booth.

FACTORS THAT AFFECT IMPACT

- Number of vehicles built
- Efficiency of controls and efforts to reduce emissions, including pollution prevention
- Exposure to impacts (population in vicinity of manufacturing facility)

[10] Tables for 1988 to 1996 include only chemicals that were reportable in all years for 1988 to 1996. These tables do not include, for example, chemicals added in 1990, 1991, 1994, or 1995. Because non-fibrous forms of aluminum were removed from the list in 1989, aluminum oxide is not included. Reporting definitions for ammonia, hydrochloric acid and sulfuric acid have also changed, and are not included in multi-year comparisons. The set of “core” chemicals differs depending on which years are being examined, so the figures in this table may not equal those in other tables that use different years.

INDICATORS OF ENVIRONMENTAL IMPACT

ESTIMATES FROM NATIONAL INVENTORIES

Quantified information on criteria pollutant emissions from vehicle and parts manufacturing facilities can be extracted from EPA's national emissions inventory. These estimates include only point sources.

Table 3-8: Criteria Pollutant Emissions from Vehicle Manufacturing Facilities, 1990-1996 (short tons)

Year	VOC	NO_x	CO	SO_2	PM-10
1990	108,050	20,848	22,046	41,670	4,616
1991	102,731	16,905	16,744	30,893	4,692
1992	107,456	21,445	17,093	35,489	5,192
1993	108,488	19,796	14,927	32,335	5,514
1994	113,542	19,583	18,008	31,468	5,641
1995	108,678	18,900	18,286	31,232	4,923
1996	102,782	18,913	18,384	31,233	4,922

Note: Based on following SIC codes — 3711, 3713, 3714, 3715, 3716, 3751, 4213.

Source: U.S. Environmental Protection Agency. *NET Viewer*.

Motor vehicle and car bodies (SIC 3711) report the largest quantity of emissions of all facilities within the vehicle manufacturing industry.

Table 3-9: Criteria Pollutant Emissions from Vehicle Manufacturing Facilities by SIC Code, 1996 (short tons)

SIC	Industry Type	VOC	NO_x	CO	SO_2	PM-10
3711	Motor Vehicles and Car Bodies	73,936	8,683	12,528	16,641	1,803
3713	Truck and Bus Bodies	7,299	164	59	59	74
3714	Motor Vehicle Parts & Accessories	16,174	9,924	5,704	14,311	2,794
3715	Truck Trailers	2,092	27	15	25	162
3716	Motor Homes	183	3	18	0	0
3537	Indust. Trucks, Tractors, Trailers, Stackers	520	39	27	2	24
3751	Motorcycles, Bicycles & Parts	2,475	53	27	152	60
4213	Trucking	103	21	7	42	4
-	TOTAL	102,782	18,913	18,384	31,233	4,922

Source: U.S. Environmental Protection Agency. *NET Viewer*.

Most of the VOC emissions from vehicle manufacturing facilities come from solvent utilization in surface coating for vehicles.

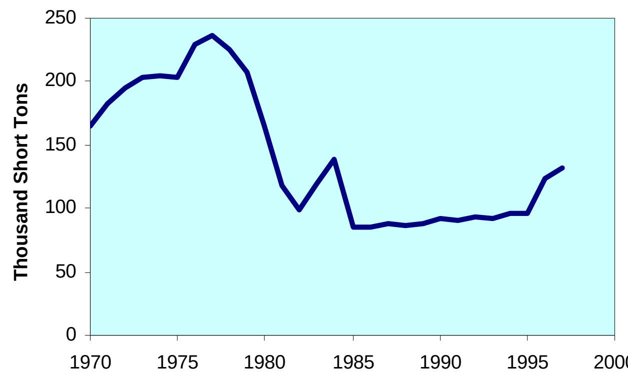
Estimates of total VOC emissions from solvent use in surface coating for autos and light trucks are available for 1970 to 1997. The estimates reported below include both point and area sources, so the figures do not correspond to the figures reported above by SIC category, which only include point sources.

Table 3-10: VOC Emissions from Solvent Utilization in Surface Coating for Autos & Light Trucks (Point and Area Sources), 1970-1997

Year	Thousand Short Tons
1970	165
1975	204
1980	165
1985	85
1990	92
1991	90
1992	93
1993	92
1994	96
1995	96
1996	123
1997	132

Source: U.S. Environmental Protection Agency. *National Air Pollutant Emissions Trends Report, 1900-1997* (Table A-3).

Figure 3-1: VOC Emissions from Solvent Utilization in Surface Coating for Autos & Light Trucks



REPORTS FROM LARGE MANUFACTURING FACILITIES

Reports of criteria pollutant emissions from individual large manufacturing facilities are compiled in EPA's AIRS database. These data are not complete. They do not include information from all manufacturing facilities or allow consistent tracking of trends. They do, however, provide a basis for comparing the contribution of motor vehicle manufacturing facilities to that of other industrial facilities.

Table 3-11: VOC Emissions from Motor Vehicle and Parts Manufacturing Facilities reported to AIRS

Industry Type (SIC)	Number of Facilities Reporting VOC	Percent of Total Facilities Reporting	Pollutant Emissions (tons/year)	Percent of Total Emissions
3465 - Automotive Stampings	2	0.05%	662	0.04%
3711 - Motor Vehicles And Car Bodies	56	1.46%	52,515	2.94%
3713 - Truck And Bus Bodies	21	0.55%	6,087	0.34%
3714 - Motor Vehicle Parts & Accessories	57	1.48%	14,363	0.8%
3715 - Truck Trailers	7	0.18%	1,744	0.1%
3716 - Motor Homes	1	0.03%	126	0.01%
3751 - Motorcycles Bicycles & Parts	6	0.16%	2,149	0.12%
3792 - Travel Trailers And Campers	5	0.13%	692	0.04%
5013 - Automotive Parts And Supplies	1	0.03%	136	0.01%
TOTAL - Motor Vehicle Manufacture	**156**	**4.1%**	**78,474**	**4.4%**

Source: U.S. EPA, Office of Air and Radiation. *AIRS Database*. January 1999.

Table 3-12: CO Emissions from Motor Vehicle and Parts Manufacturing Facilities reported to AIRS

Industry Type (SIC)	Number of Facilities Reporting VOC	Percent of Total Facilities Reporting	Pollutant Emissions (tons/year)	Percent of Total Emissions
3711 - Motor Vehicles And Car Bodies	3	0.59%	4,490	0.12%
3714 - Motor Vehicle Parts & Accessories	1	0.2%	1,390	0.04%
TOTAL - Motor Vehicle Manufacture	**4**	**0.79%**	**5,880**	**0.16%**

Source: U.S. EPA, Office of Air and Radiation. *AIRS Database.* January 1999.

Table 3-13: NO_2 Emissions from Motor Vehicle and Parts Manufacturing Facilities reported to AIRS

Industry Type (SIC)	Number of Facilities Reporting VOC	Percent of Total Facilities Reporting	Pollutant Emissions (tons/year)	Percent of Total Emissions
3711 - Motor Vehicles And Car Bodies	23	0.5%	6,602	0.08%
3714 - Motor Vehicle Parts & Accessories	20	0.43%	8,891	0.1%
TOTAL - Motor Vehicle Manufacture	**43**	**0.93%**	**15,493**	**0.18%**

Source: U.S. EPA, Office of Air and Radiation. *AIRS Database.* January 1999.

Table 3-14: SO_2 Emissions from Motor Vehicle and Parts Manufacturing Facilities reported to AIRS

Industry Type (SIC)	Number of Facilities Reporting VOC	Percent of Total Facilities Reporting	Pollutant Emissions (tons/year)	Percent of Total Emissions
3711 - Motor Vehicles And Car Bodies	14	0.58%	5,795	0.04%
3714 - Motor Vehicle Parts & Accessories	19	0.79%	6,966	0.04%
3751 - Motorcycles Bicycles & Parts	1	0.04%	118	0%
5013 - Automotive Parts And Supplies	1	0.04%	116	0%
TOTAL - Motor Vehicle Manufacture	**35**	**1.45%**	**12,995**	**0.08%**

Source: U.S. EPA, Office of Air and Radiation. *AIRS Database.* January 1999.

Table 3-15: PM_{10} Emissions from Motor Vehicle and Parts Manufacturing Facilities reported to AIRS

Industry Type (SIC)	Number of Facilities Reporting VOC	Percent of Total Facilities Reporting	Pollutant Emissions (tons/year)	Percent of Total Emissions
3711 - Motor Vehicles And Car Bodies	1	0.09	221	0.05
3715 - Truck Trailers	1	0.09	135	0.03
TOTAL - Motor Vehicle Manufacture	**2**	**0.18**	**356**	**0.08**

Source: U.S. EPA, Office of Air and Radiation, *AIRS Database.* January 1999.

3.3 ON-ROAD VEHICLE TRAVEL

Road vehicle travel is the dominant form of transportation in the United States. In 1997, about 2.56 trillion vehicle miles were traveled on U.S. roads by passenger cars, motorcycles, buses, light-duty trucks, and heavy-duty trucks.[11] Vehicle travel has increased rapidly — rising from 719 billion miles in 1960, to 1.11 trillion miles in 1970, to 1.53 trillion miles in 1980, and to 2.14 trillion miles in 1990.

Air pollution from motor vehicles is the most widely recognized and studied environmental impact of transportation. Air pollution from vehicle travel comes from by-products of the combustion process and evaporation of unburned fuel, as well as particulate matter that is entrained by passing automobiles. Vehicle travel also causes other adverse effects, such as greenhouse gas emissions, noise problems, collisions with wildlife, and water quality impacts from oil leaks. Hazardous materials incidents during highway transport may release harmful chemicals to the environment.

TAILPIPE AND EVAPORATIVE EMISSIONS

DESCRIPTION OF IMPACT

On-road vehicle travel results in emissions of pollutants that are harmful to human health and welfare. Carbon monoxide (CO), sulfur oxides (SO_x), oxides of nitrogen (NO_x), volatile organic compounds (VOC), and particulate matter (PM) are by-products of the internal combustion process and are emitted directly from vehicle exhaust. VOCs are also emitted during fuel evaporation. Evaporation occurs from vaporization of gasoline during travel (running losses), after parking while the engine is still warm (hot soak), vapors escaping while refueling the vehicle, and even as a vehicle sits parked while the engine is cool on hot summer days (diurnal emissions).

Toxic air pollutants are also emitted by motor vehicles. Many toxic air pollutants are emitted in the form of particulates or VOC. Major hazardous air pollutants emitted by motor vehicles include Acetaldehyde, Benzene, 1,3-Butadiene, Formaldehyde, Toluene, and Xylenes.

Modern emissions control equipment has significantly reduced the rate at which vehicles emit pollutants from the tailpipe. Lead emissions have been virtually eliminated due to the phase-out of leaded gasoline. Increasingly stringent vehicle emissions standards and reformulated and oxygenated fuels have led to significant progress at controlling vehicle emissions. In fact, on-road vehicle emissions have fallen since the 1970s despite rapid growth in vehicle travel. Still, challenges remain because rapid growth in travel has offset some of the potential emissions reductions from improved technologies and continued vehicle travel growth threatens air quality in many urban areas.

FACTORS THAT AFFECT IMPACT

Factors that affect the amount of emissions coming from motor vehicles include:

- Number of vehicle trips - number of cold-starts, hot-starts, hot-soaks

[11] U.S. Department of Transportation, Federal Highway Administration. *Highway Statistics 1997* (Table VM-1).

- Vehicle miles of travel (VMT)
- Vehicle type, age, weight, and emissions control technology
- Type of fuel consumed (gasoline, diesel fuel, etc.)
- Travel characteristics: speed, acceleration, etc. - affects emissions per mile

Factors that influence the amount of environmental damage that occurs from air pollutant emissions include:

- Topographical conditions (hills, valleys, etc.) - affects dispersion/dilution of pollutants
- Climatic conditions (temperature, wind, rain, etc.) - affects dispersion/dilution of pollutants and formation of secondary pollutants
- Population density - affects number of people exposed to pollution
- Sensitivity of local ecosystems

INDICATORS OF ENVIRONMENTAL IMPACT

AIR POLLUTANT EMISSIONS

A large portion of national emissions of carbon monoxide, volatile organic compounds, and oxides of nitrogen come from motor vehicle travel. Although there has been a steady trend of improvement in air quality since the 1970s, air pollutant emissions from motor vehicle travel still remain a major challenge for many urban areas that fail to meet national air quality standards.

Table 3-16: Criteria Pollutant Emissions from Motor Vehicle Travel, 1997

Pollutant	Quantity Emitted (thousand short tons)	Percent of total Emissions of Pollutant
Carbon Monoxide (CO)	50,257	57.5%
Nitrogen Oxides (NO_x)	7,035	29.8%
Volatile Organic Comp. (VOCs)	5,230	27.2%
Sulfur Dioxide (SO_2)	340	1.6%
Particulate Matter (PM_{10})	268	8.6%*
Particulate Matter ($PM_{2.5}$)	207	9.2%*
Lead (Pb)	0.019	0.5%

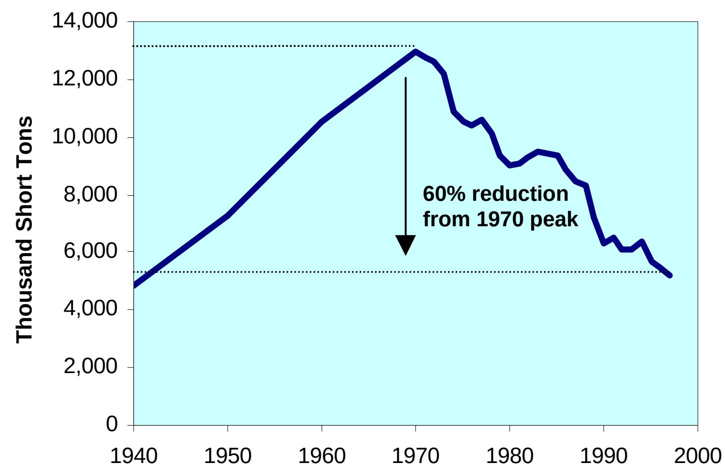
*Note: Percentage of emissions from traditionally inventoried sources (does not include agriculture and forestry, fugitive dust, or natural sources like windblown dust)

Source: U.S. Environmental Protection Agency. *National Air Pollutant Emission Trends, 1900-1997.*

Table 3-17: VOC Emissions from On-Road Vehicles, 1940-1997

Year	Thousand Short Tons
1940	4,817
1950	7,251
1960	10,506
1970	12,972
1980	8,979
1985	9,376
1986	8,874
1987	8,477
1988	8,290
1989	7,192
1990	6,313
1991	6,499
1992	6,072
1993	6,103
1994	6,401
1995	5,701
1996	5,502
1997	5,230

Figure 3-2: VOC Emissions from On-Road Vehicles



Source: U.S. Environmental Protection Agency, *National Air Pollutant Emissions Trends, 1900-1997* (Table A-3).

Table 3-18: VOC Emissions by On-Road Vehicle Category (thousand short tons), 1970-1990

Year	Gas			Diesel		
	Light-Duty Vehicles*	Light-Duty Trucks	Heavy-Duty Vehicles	Light-Duty Vehicles	Light-Duty Trucks	Heavy-Duty Vehicles
1970	9,193	2,770	743	NA	NA	266
1975	7,248	2,289	657	15	NA	335
1980	5,907	2,059	611	8	2	392
1985	5,864	2,425	716	8	2	360
1990	3,947	1,622	432	13	3	297
1991	4,069	1,688	423	12	3	304
1992	3,832	1,588	334	13	3	302
1993	3,812	1,647	326	13	3	301
1994	3,748	1,909	414	13	4	313
1995	3,426	1,629	327	14	4	302
1996	2,875	2,060	293	12	5	245
1997	2,755	1,968	268	12	5	221

*includes motorcycles

Source: U.S. Environmental Protection Agency, *National Air Pollutant Emissions Trends, 1900-1997* (Table A-3).

Table 3-19: NO_X Emissions from On-Road Vehicles, 1940-1997

Year	Thousand Short Tons
1940	1,330
1950	2,143
1960	3,982
1970	7,390
1980	8,621
1985	8,089
1986	7,773
1987	7,651
1988	7,661
1989	7,682
1990	7,040
1991	7,373
1992	7,440
1993	7,510
1994	7,672
1995	7,323
1996	7,171
1997	7,035

Source: U.S. Environmental Protection Agency, *National Air Pollutant Emissions Trends, 1900-1997* (Table A-2).

Figure 3-3: NO_X Emissions from On-Road Vehicles

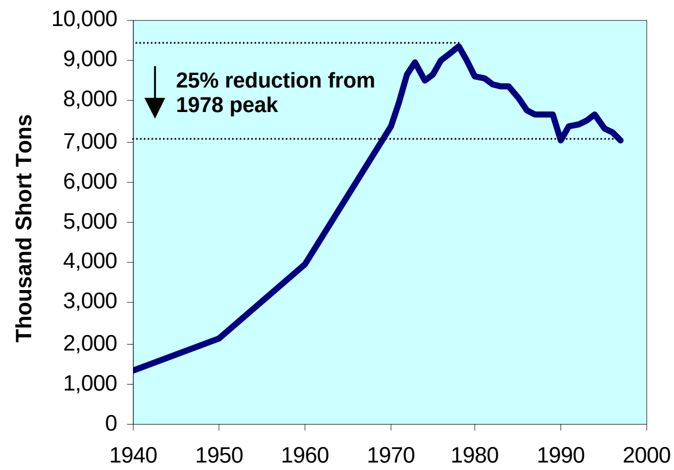


Table 3-20: NO_X Emissions by On-Road Vehicle Category (thousand short tons), 1970-1997

Year	Gas			Diesel		
	Light-Duty Vehicles*	Light-Duty Trucks	Heavy-Duty Vehicles	Light-Duty Vehicles	Light-Duty Trucks	Heavy-Duty Vehicles
1970	4,158	1,278	278	NA	NA	1,676
1975	4,725	1,461	319	23	NA	2,118
1980	4,421	1,408	300	25	5	2,463
1985	3,806	1,530	330	28	6	2,389
1990	3,220	1,256	326	39	7	2,192
1991	3,464	1,339	326	37	8	2,199
1992	3,614	1,356	308	39	8	2,116
1993	3,680	1,420	315	39	8	2,047
1994	3,573	1,657	351	38	10	2,043
1995	3,444	1,520	332	39	10	1,979
1996	2,979	1,950	329	35	13	1,941
1997	2,875	1,901	326	35	12	1,886

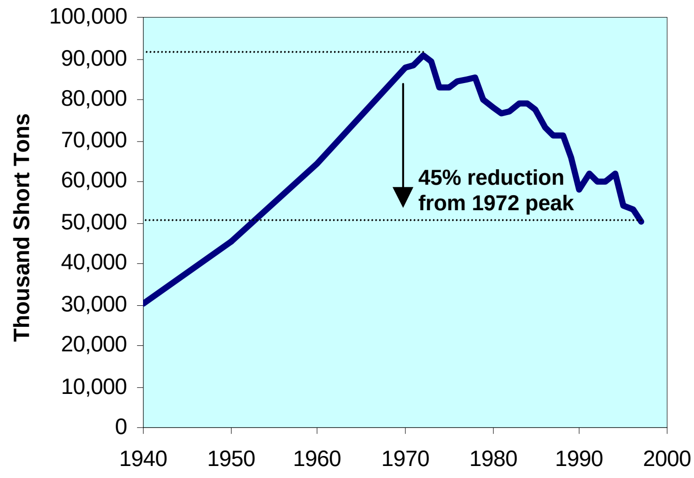
*includes motorcycles

Source: U.S. Environmental Protection Agency, *National Air Pollutant Emissions Trends, 1900-1997* (Table A-2).

Table 3-21: CO Emissions from On-Road Vehicles, 1940-1997

Year	Thousand Short Tons
1940	30,121
1950	45,196
1960	64,266
1970	88,034
1980	78,049
1985	77,387
1986	73,347
1987	71,250
1988	71,081
1989	66,050
1990	57,848
1991	62,074
1992	59,859
1993	60,202
1994	61,833
1995	54,106
1996	53,262
1997	50,257

Figure 3-4: CO Emissions from On-Road Vehicles



Source: U.S. Environmental Protection Agency, *National Air Pollutant Emissions Trends, 1900-1997* (Table A-1).

Table 3-22: CO Emissions by On-Road Vehicle Category (thousand short tons), 1970-1997

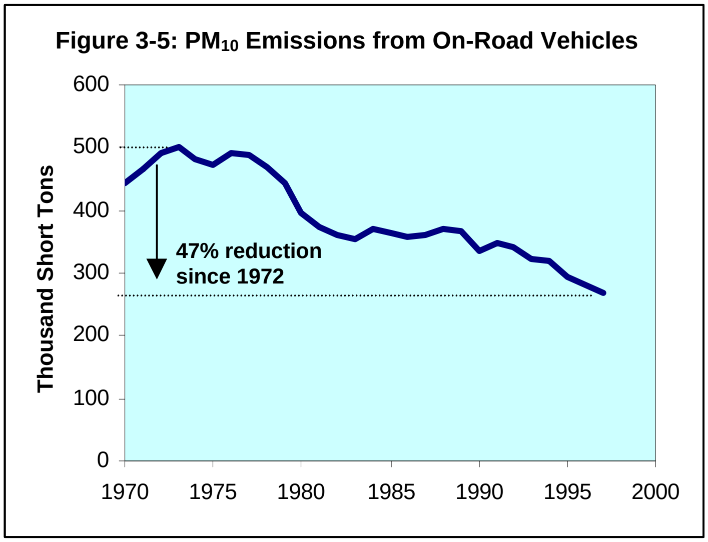
Year	Gas			Diesel		
	Light-Duty Vehicles*	Light-Duty Trucks	Heavy-Duty Vehicles	Light-Duty Vehicles	Light-Duty Trucks	Heavy-Duty Vehicles
1970	64,031	16,570	6,712	NA	NA	721
1975	59,281	15,767	7,140	30	NA	915
1980	53,561	16,137	7,189	19	4	1,139
1985	49,451	18,960	7,716	22	4	1,235
1990	37,407	13,816	5,360	31	5	1,229
1991	40,267	15,014	5,459	30	6	1,298
1992	39,370	14,567	4,569	31	6	1,315
1993	39,163	15,196	4,476	33	7	1,328
1994	37,507	17,350	5,525	32	8	1,411
1995	33,701	14,829	4,123	33	8	1,412
1996	28,732	19,271	3,766	29	11	1,453
1997	27,036	18,364	3,349	30	11	1,468

*includes motorcycles

Source: U.S. Environmental Protection Agency, *National Air Pollutant Emissions Trends, 1900-1997* (Table A-1).

Table 3-23: PM$_{10}$ Emissions from On-Road Vehicles, 1940-1997

Year	Thousand Short Tons
1970	443
1975	471
1980	397
1985	363
1986	356
1987	360
1988	369
1989	367
1990	336
1991	349
1992	343
1993	321
1994	320
1995	293
1996	282
1997	268



Source: U.S. Environmental Protection Agency, *National Air Pollutant Emissions Trends, 1900-1997* (Table A-5).

Table 3-24: PM$_{10}$ Emissions by On-Road Vehicle Category (thousand short tons), 1970-1997

Year	Gas			Diesel		
	Light-Duty Vehicles*	Light-Duty Trucks	Heavy-Duty Vehicles	Light-Duty Vehicles	Light-Duty Trucks	Heavy-Duty Vehicles
1970	225	70	13	NA	NA	136
1975	207	72	15	10	NA	166
1980	120	55	15	12	2	194
1985	77	43	14	8	1	219
1990	61	30	10	9	1	224
1991	63	32	10	9	2	234
1992	64	31	9	9	2	228
1993	65	31	10	8	2	205
1994	62	35	10	8	2	204
1995	62	32	9	8	2	181
1996	55	41	9	7	2	168
1997	56	40	9	6	2	154

*includes motorcycles

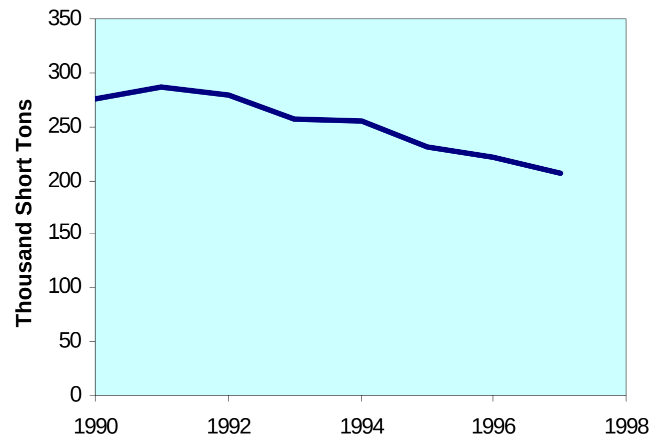
Source: U.S. Environmental Protection Agency, *National Air Pollutant Emissions Trends, 1900-1997* (Table A-5).

Table 3-25: $PM_{2.5}$ Emissions from On-Road Vehicles, 1990-1997

Year	Thousand Short Tons
1990	275
1991	286
1992	280
1993	257
1994	256
1995	231
1996	221
1997	207

Source: U.S. Environmental Protection Agency, *National Air Pollutant Emissions Trends, 1900-1997* (Table A-6).

Figure 3-6: $PM_{2.5}$ Emissions from On-Road Vehicles



Diesel vehicles produce most of the $PM_{2.5}$ emissions from on-road vehicles.

Table 3-26: $PM_{2.5}$ Emissions by On-Road Vehicle Category (thousand short tons), 1970-1997

Year	Gas			Diesel		
	Light-Duty Vehicles*	Light-Duty Trucks	Heavy-Duty Vehicles	Light-Duty Vehicles	Light-Duty Trucks	Heavy-Duty Vehicles
1990	37	19	7	*8*	1	212
1991	38	21	6	*8*	1	221
1992	37	20	6	*8*	2	216
1993	38	20	7	*7*	1	192
1994	36	23	7	*7*	2	190
1995	36	20	6	*7*	2	169
1996	32	25	6	*6*	2	157
1997	32	25	*6*	*6*	2	144

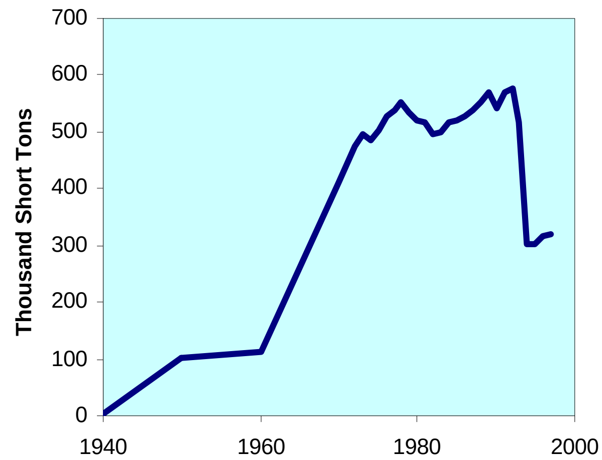
*includes motorcycles

Source: U.S. Environmental Protection Agency, *National Air Pollutant Emissions Trends, 1900-1997* (Table A-6).

Table 3-27: SO_2 Emissions from On-Road Vehicles, 1940-1997

Year	Thousand Short Tons
1940	3
1950	103
1960	114
1970	411
1980	521
1985	522
1986	527
1987	538
1988	553
1989	570
1990	542
1991	570
1992	578
1993	517
1994	301
1995	304
1996	316
1997	320

Figure 3-7: SO_2 Emissions from On-Road Vehicles



Source: U.S. Environmental Protection Agency. *National Air Pollutant Emissions Trends, 1900-1997* (Table A-4).

Table 3-28: SO_2 Emissions by On-Road Vehicle Category (thousand short tons), 1970-1997

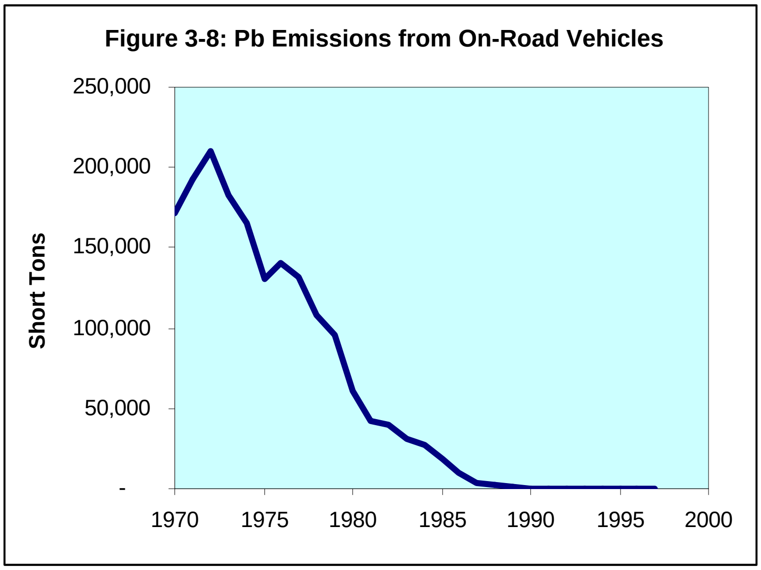
Year	Gas			Diesel
	Light-Duty Vehicles*	Light-Duty Trucks	Heavy-Duty Vehicles	
1970	132	40	8	231
1975	158	48	9	288
1980	159	50	10	303
1985	146	55	11	311
1990	138	57	11	337
1991	143	59	10	358
1992	146	59	10	363
1993	147	60	11	299
1994	141	70	12	79
1995	143	71	11	80
1996	127	95	11	83
1997	129	96	11	84

*includes motorcycles

Source: U.S. Environmental Protection Agency. *National Air Pollutant Emissions Trends, 1900-1997* (Table A-4).

Table 3-29: Lead Emissions from On-Road Vehicles, 1940-1997

Year	Short Tons
1970	171,961
1975	130,206
1980	60,501
1985	18,052
1986	10,245
1987	3,317
1988	2,566
1989	982
1990	421
1991	18
1992	18
1993	19
1994	19
1995	19
1996	20
1997	19



Source: U.S. Environmental Protection Agency. *National Air Pollutant Emission Trends, 1900-1996* (Table A-6).

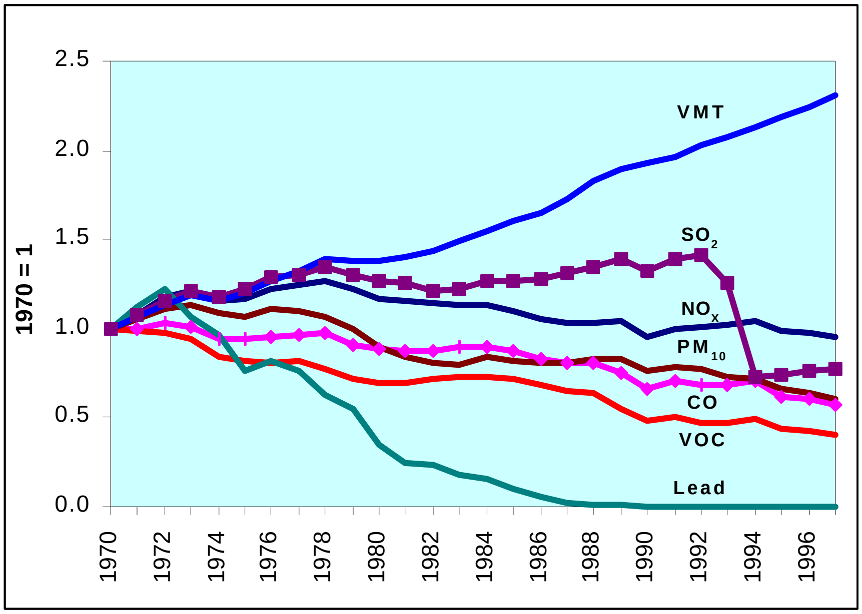
Table 3-30: Lead Emissions by On-Road Vehicle Category (short tons), 1970-1997

Year	Gas		
	Light-Duty Vehicles*	Light-Duty Trucks	Heavy-Duty Vehicles
1970	142,918	22,683	6,361
1975	106,868	19,440	3,898
1980	47,184	11,671	1,646
1985	13,637	4,061	354
1990	314	100	7
1991	13	4	0
1992	14	4	0
1993	14	5	0
1994	14	5	0
1995	14	5	0
1996	12	7	0
1997	12	7	0

Source: U.S. Environmental Protection Agency. *National Air Pollutant Emission Trends, 1900-1996* (Table A-6).

Despite increasing vehicle travel, emissions of all criteria pollutants from motor vehicles have fallen since 1970. These improvements stem from actions taken as a result of the Clean Air Act, such as improved vehicle technologies and cleaner burning fuels.

Figure 3-9: Change in Criteria Pollutant Emissions compared to Vehicle Travel, 1940-1997



TOXIC EMISSIONS

On-road vehicles are by far the largest source of toxic emissions, emitting about 1,389,111 short tons per year of hazardous air pollutants.

Source: U.S. Environmental Protection Agency. *National Toxics Inventory.* Referenced in: U.S. Environmental Protection Agency. *National Air Pollutant Emission Trends 1900-1996.* January 1998 (Table 8-1).

Table 3-31: Motor Vehicle Emissions of Toxic Pollutants, 1990

Hazardous Air Pollutant	Quantity Emitted (metric tons)	Percent of Total Emission
Benzene	158,149	60%
Formaldehyde	73,874	33%
1,3 Butadiene	27,972	56%

Source: U.S. Environmental Protection Agency. *Motor Vehicle-Related Air Toxics Study.* April 1993. http://www.epa.gov/OMSWWW/toxics.htm

FUGITIVE DUST EMISSIONS FROM ROADS

DESCRIPTION OF IMPACT

Vehicle travel kicks up dust and dirt from paved and unpaved road surfaces. Dust generated from road travel is called "fugitive" because it does not enter the atmosphere in a confined flow stream. Fugitive dust from travel on roads constitutes a large portion of national PM_{10} and $PM_{2.5}$ emissions.

Fugitive dust emissions are highest from unpaved roads. The quantity of dust emissions from a given section of unpaved road varies roughly linearly with the volume of traffic. When a vehicle traverses a segment of unpaved road, the force of the wheels on the road surface causes pulverization of surface material. Particles are lifted and dropped from the rolling wheels, and the road surface is exposed to strong air currents in turbulent shear with the surface. The turbulent wake behind the vehicle continues to act on the surface after the vehicle has passed.

Fugitive dust from paved roads consists primarily of mineral matter, similar to common sand and soil, mostly tracked or deposited onto the roadway by vehicle traffic itself. Vehicle carryout from unpaved areas is probably the largest single source of street deposit. It is notable that paved road mileage has been growing rapidly, as existing roads are paved at a much higher rate than new roads are built. As recently as around 1975, unpaved mileage exceeded paved mileage.

CAUSAL FACTORS

- Lane mileage, paved and unpaved
- VMT, by pavement type
- Topographical conditions (hills, valleys, etc.) affecting pollutant dispersion
- Climatic conditions (temperature, wind, rain, etc.) affecting pollutant dispersion and secondary pollutant formation
- Population density affecting potential exposure

INDICATORS OF ENVIRONMENTAL IMPACT

Fugitive dust from roads made up 44% of total PM_{10} emissions and 30% of $PM_{2.5}$ emissions in 1997.

Source: U.S. Environmental Protection Agency. *National Air Pollutant Emission Trends, 1900-1997* (Tables A-5 and A-6).

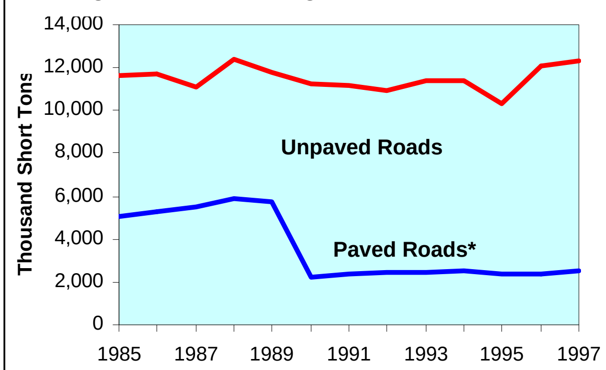
Although unpaved roads comprise about 39% of total road mileage in the U.S., they accounted for 83% of the PM_{10} emissions from road dust in 1997.

Table 3-32: PM_{10} Fugitive Dust, Emissions by Road Type, 1985-1997 (thousand short tons)

Year	Unpaved roads	Paved roads
1985	11,664	5,080
1990	11,234	2,248
1991	11,206	2,399
1992	10,918	2,423
1993	11,430	2,462
1994	11,370	2,538
1995	10,362	2,409
1996	12,060	2,390
1997	12,305	2,515

Note: Change in methodology for estimating PM_{10} emissions between 1985 and 1990.
Source: U.S. Environmental Protection Agency. *National Air Pollutant Emission Trends, 1900-1997* (Table A-5).

Figure 3-10: PM_{10} Fugitive Dust Emissions



*Note: Change in methodology for estimating PM_{10} emissions between 1985 and 1990.

GREENHOUSE GAS EMISSIONS

DESCRIPTION OF IMPACT

Motor vehicles are a significant user of fossil fuels, which release carbon dioxide in the combustion process. Since more carbon dioxide emissions are released as more fuel is consumed, vehicle fuel economy and levels of vehicle travel are the primary determinants of carbon emissions. Nationally, fuel economy by vehicle category (e.g., automobiles, light-duty trucks, etc.) has been stable in recent years, and there has been a shift toward more travel by less-fuel efficient categories of vehicles, such as sports utility vehicles and light trucks.

Motor vehicle travel also releases other greenhouse gases, like methane and nitrous oxide. Transportation-related criteria pollutants, including carbon monoxide, oxides of nitrogen, and nonmethane volatile organic compounds, indirectly affect climate because they alter atmospheric concentrations of carbon dioxide, methane, and ozone.

FACTORS THAT AFFECT IMPACT

- Vehicle miles of travel
- Vehicle fuel economy
- Type of fuel being used
- Vehicle technology

INDICATORS OF ENVIRONMENTAL IMPACT

CARBON DIOXIDE EMISSIONS

In 1996, carbon dioxide emissions from on-road vehicles accounted for approximately 341.1 million metric tons of carbon (MMTC). This equals about 76.6 percent of total CO_2 emissions from the transportation sector, or about 23.5 percent of CO_2 emissions from fossil fuel combustion. Carbon emissions from motor vehicles increased about 11 percent between 1990 and 1996.

Table 3-33: Carbon Dioxide Emissions by On-Road Vehicle Category (million metric tons of carbon)

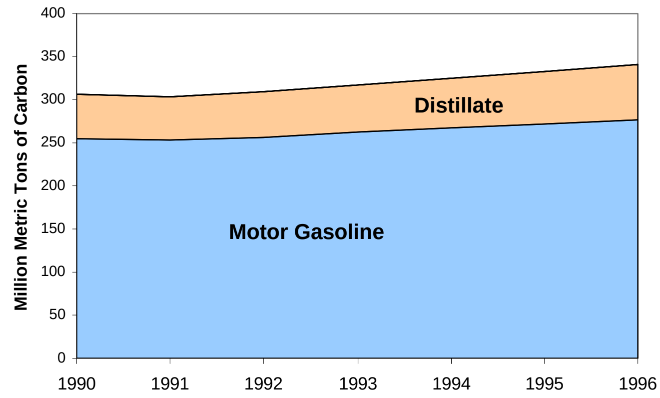
Year	Motor Gasoline					Distillate Fuel Oil (Diesel)					LPG	Total
	Passenger Cars *	Light Duty Trucks *	Other Trucks	Buses	Total Motor Gasoline	Passenger Cars	Light Duty Trucks	Other Trucks	Buses	Total Distillate Fuel Oil		
1990	167.7	74.9	11.3	0.6	254.5	2	2.5	45.3	2.2	52	0.3	306.8
1991	166.3	74.7	11.2	0.6	252.8	1.9	2.4	43.3	2.2	49.8	0.3	302.9
1992	170.4	74.6	11.2	0.6	256.8	2	2.5	45.1	2.3	51.9	0.3	309.0
1993	171.9	77.8	11.7	0.7	262.1	2	2.6	47.7	2.3	54.6	0.3	317.0
1994	171.0	84.2	10.4	0.9	266.5	2	2.8	51.7	2.3	58.8	0.3	325.6
1995	158.6	101.3	10.9	0.8	271.6	1.8	3.3	52.7	2.7	60.5	0.3	332.4
1996	161.8	103.4	11.2	0.8	277.2	1.9	3.4	55.5	2.8	63.6	0.3	341.1

*Note: In 1995, FHWA changed the definition of light duty trucks to include minivans and SUVs. Previously, they were included in the passenger car category, hence the drop in emissions for passenger cars from 1994 to 1995 which is, however, offset by a rise in light duty truck emissions.

Source: U.S. Environmental Protection Agency, Office of Policy, Planning and Evaluation. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1996.* March 1998 (Table 2-6).

In contrast to criteria air pollutants, carbon dioxide emissions from motor vehicles have been rising. Total highway fuel use actually declined over the period 1979 to 1982, but has since been rising due to increases in vehicle travel that have more than offset increases in vehicle fuel economy. Although fuel economy of gasoline personal vehicles has improved in the U.S., from about 13.2 miles per gallon in 1970 to 20.2 miles per gallon in 1993, fuel economy has since been flat and is projected to decline, in part due to a shift from automobiles to less fuel efficient light-trucks.[12]

Figure 3-11: CO_2 Emissions from Motor Vehicles



NITROUS OXIDE EMISSIONS

Motor vehicles emit approximately 22 percent of national emissions of nitrous oxide. Nitrous oxide emissions from motor vehicles increased by 33 percent between 1990 and 1997.

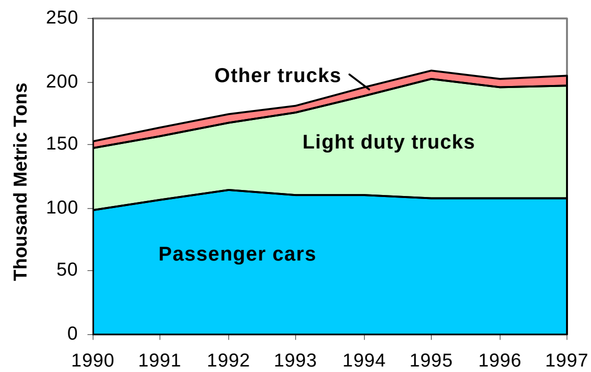
Table 3-34: Nitrous Oxide Emissions from Motor Vehicles (thousand metric tons)

Year	Passenger cars	Light duty trucks	Other trucks	Buses	Total Motor Vehicles
1990	99	48	6	<0.5	154
1991	106	51	6	<0.5	164
1992	115	53	6	<0.5	174
1993	111	64	6	<0.5	182
1994	111	78	7	<0.5	196
1995	108	94	7	<0.5	209
1996	108	87	7	<0.5	202
1997	108	89	8	<0.5	205

Source: U.S. Department of Energy, Energy Information Administration. *Emissions of Greenhouse Gases in the United States 1997.* October 1998 (Table 26).

[12] U.S. Department of Energy. *Transportation Energy Databook Edition 18.* 1998.

Figure 3-12: N_2O Emissions from Motor Vehicles



METHANE EMISSIONS

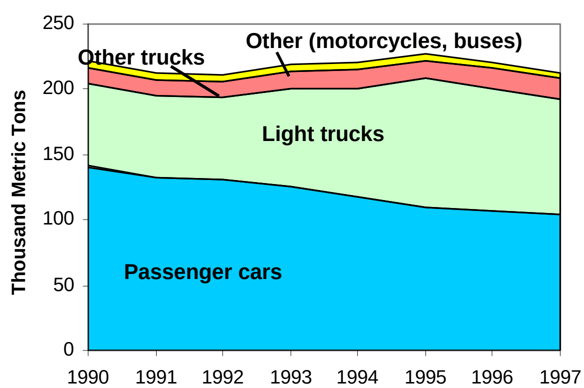
Motor vehicles emit less than 1 percent of methane emissions nationwide. Methane emissions from motor vehicles have been fairly stable since 1990

Table 3-35: Methane Emissions from Motor Vehicles (thousand metric tons)

Year	Passenger cars	Light duty trucks	Other trucks	Buses	Total Motor Vehicles
1990	141	63	12	1	222
1991	132	63	12	1	211
1992	131	63	12	1	211
1993	126	75	13	1	218
1994	117	84	14	1	220
1995	109	99	14	1	228
1996	107	94	15	1	220
1997	104	89	15	1	213

Source: U.S. Department of Energy, Energy Information Administration. *Emissions of Greenhouse Gases in the United States 1997.* October 1998 (Table 26).

Figure 3-13: CH_4 Emissions from Motor Vehicles



EMISSIONS OF REFRIGERANT AGENTS FROM VEHICLE AIR CONDITIONERS

DESCRIPTION OF IMPACT

Automobile air conditioners are subject to significant leakage, with nearly all of the refrigerant leaking out over a 5-year time period. Until recently, the chlorofluorocarbon CFC-12 (also known as Freon-12) was the principal refrigerant agent used in automobile air conditioners. Other major end uses of CFC-12 include commercial air conditioning, refrigeration (refrigerators and freezers), and a blowing agent for foams, insulation, and packaging. CFCs are responsible for depletion of the stratospheric ozone layer. Stratospheric ozone, beneficial for its ability to absorb UV radiation, is, however, also a greenhouse gas. Gases that destroy stratospheric ozone thus have indirect cooling effects. Chlorine-containing chemicals such as CFCs tend to react with ozone, and the net effect on global climate is ambiguous.[13]

By signing the *Montreal Protocol on Substances that Deplete the Ozone Layer* and *Copenhagen Amendments*, the United States committed to eliminating the production of all CFCs by the end of 1995. On December 31, 1995, CFC-12 production essentially ended in the U.S. It is still legal to use existing stockpiles of CFC-12, but several companies have also developed new substitutes. The 1990 Clean Air Act Amendments (CAAA) directed EPA to develop regulations to maximize recycling, ban nonessential uses, develop labeling requirements, and examine safe alternatives. Recycling occurs in a service shop involves use of a machine to remove impurities and oil and then recharge the refrigerant into either the same car or a different car. Reclamation involves removal of all oil and impurities beyond that provided by on-site recycling equipment, and reclaimed refrigerant is essentially identical to new, unused refrigerant.

Hydrofluorocarbon HFC-134a became the standard automobile air conditioner refrigerant in 1994, and HFC emissions have been growing as CFCs gradually disappear from the automobile fleet. HFCs, which contain no chlorine, have no effect on ozone, but they are a greenhouse gas. Automobile air conditioners are the principal end-use for HFC-134a. As of 1994, practically all new automobiles were using HFC-134a as the refrigerant in their air conditioners, and many manufacturers now offer conversion packages through their dealerships.[14]

HFC-134a has a lifetime of 15 years and one molecule has a 100-year global warming potential 1,300 times that of one molecule of CO_2. The lack of chlorine in HFCs and their shorter atmospheric lifetimes reduce the indirect cooling effects of CFCs. Thus, HFC replacement compounds may be worse from a global climate perspective than their predecessors.

FACTORS THAT AFFECT IMPACT

- Quantity of refrigerant agent used
- Net global warming potential of refrigerant agent used
- Net ozone depleting potential of refrigerant agent used

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[13] U.S. Department of Energy. *Emissions of Greenhouse Gases in the United States 1995.* October 1998 (pp. 4-5).

[14] U.S. Department of Energy. *Emissions of Greenhouse Gases in the United States 1995.* October 1998 (pp. 57-58).

INDICATORS OF ENVIRONMENTAL IMPACT

CFC AND HFC EMISSIONS

Quantified data on the contribution of vehicle refrigerant agents to depletion of the ozone layer and global warming are not available.

About 24,000 metric tons of CFC-12 were released in 1997 from all sources (not only vehicles), down significantly from the pre-Montreal Protocol level of 113,000 metric tons. HFC-134 emissions are up significantly, however.

Table 3-36: Estimated U.S. Emissions of CFC-12 and HFC-134a (all sources), 1990-1997 (thousand metric tons of gas)

Year	CFC-12	HFC-134a
1990	113	1
1991	104	1
1992	81	1
1993	79	3
1994	58	5
1995	52	10
1996	36	14
1997	24	18

Source: U.S. Department of Energy, Energy Information Administration. *Emissions of Greenhouse Gases in the United States 1997.* October 1998 (Table 31).

NOISE

DESCRIPTION OF IMPACT

Noise associated with road transport comes from engine operations, pavement-wheel contact, aerodynamic effects, and vibrating structures. Heavy trucks and buses cause more noise per vehicle than cars. The findings of numerous research projects on the effects of noise and its wider repercussions indicate that an outdoor sound level of 65 dB(A) is "unacceptable", and an outdoor level of less than 55 dB(A) is desirable.[15] Noise can cause stress and other health problems and lower property values. It can also affect local habitats of species near roads.

CAUSAL FACTORS

- Level of road activity - traffic volumes
- Speed of traffic
- Proportion of heavy vehicles (one truck emits the equivalent noise of 28 to 60 cars)
- Population density near road.
- Existence and effectiveness of noise barriers
- Effectiveness of devices such as mufflers and quiet vehicles

[15] Organization for Economic Cooperation and Development. *Indicators for the Integration of Environmental Concerns into Transport Policies.* OECD Publications. 1993.

INDICATORS OF ENVIRONMENTAL IMPACT

EXPOSURE TO TRAFFIC NOISE

Noise levels are site specific and dissipate with increasing distance from the source; as a result, there are no national estimates of total noise generated by transportation. According to one estimate, 37.0% of the U.S. population was exposed to noise levels from road transport great enough to cause annoyance—defined as Leq greater than 55dB(A)—in 1980. Smaller portions of the U.S. population were exposed to daily noise levels from road transport great enough to cause other effects, such as communication interference, muscle/gland reaction, and changed motor coordination. A more recent estimate is not available.

Table 3-37: Percent of U.S. Population Exposed to Road Transportation Noise, 1980 Outdoor Sound Level in Leq [dB(A)]

>55 dB(A) Annoyance	>60 dB(A) Normal Speech Level	>65 dB(A) Communication Interference	>70 dB(A) Muscle/Gland Reaction	>75 dB(A) Changed Motor Coordination
37.0%	18.0%	7.0%	2.0%	0.4%

Source: Organization for Economic Cooperation and Development. *Indicators for the Integration of Environmental Concerns into Transport Policies.* OECD Publications. 1993.

NOISE BARRIERS CONSTRUCTED

Noise barriers are constructed to cut exposure to high levels of highway noise, particularly along interstate highways abutting residential areas. While construction of noise barriers suggests that highway noise is a problem, barrier construction is not an indicator of an adverse environment impact per se. More construction may indicate that noise problems are being reduced. Still, the cost of barrier construction provides an indication of the price being paid to reduce highway noise exposure.

Overall, about 1.5 billion dollars is known to have been spent on highway noise barrier construction (in 1995 dollars).

Table 3-38: Length of Noise Barriers Constructed (miles) and Cost

Year of Construction	Type I Barriers	Type II Barriers	All Other Types	Length, total	Cost (millions of 1995 dollars)
Unknown	6	0	N/A	6	N/A
1970-79	104	71	2	177	130
1980-89	422	130	15	567	624
1990	45	20	1	65	92
1991	79	20	2	101	142
1992	112	19	10	141	184
1993	60	22	3	85	112
1994	41	16	4	61	72
1995	78	31	6	115	141
1970-95	**947**	**329**	**43**	**1,318**	**1,497**

Note: Data are produced on a 3-year cycle. Miles have been converted from kilometers (as cited in source). Total may not match the sum of yearly estimates due to rounding.

Source: U.S. Department of Transportation, Bureau of Transportation Statistics. *National Transportation Statistics 1998.* Table 4-45.

A Type I barrier is built on a highway project to construct a new highway or to physically alter an existing highway. A Type II barrier is built to abate noise along an existing highway (often referred to as retrofit abatement), and is not mandatory. All other types of barriers are non-Federally funded.

HAZARDOUS MATERIALS INCIDENTS DURING TRANSPORT

DESCRIPTION OF INDICATORS

The potential for commodity releases during highway transportation is important to consider because of the large and growing role truck transport plays in domestic freight movement. In 1997, truck transport accounted for 32% of the ton-miles moved during domestic intercity transport, excluding pipelines.[16] Trucks carry over 60% of the hazardous materials transported in the U.S.[17]

Commodity spills of hazardous materials may impose substantial costs for product loss, carrier damage, property damage, evacuations, and response personnel and equipment. The number of hazardous material incidents is not necessarily indicative of the environmental impact of such incidents, since it may be possible to clean up most of the materials released. If not properly contained, however, hazardous materials incidents may cause environmental damage such as air and water pollution, damage to fish and wildlife, and habitat destruction. The environmental impact of any given hazardous materials spill is highly site-specific. It depends on the type and quantity of material spilled, amount recovered in cleanup, chemical properties (such as toxicity and combustibility), and impact area characteristics (such as climatic conditions, flora and fauna density, and local topography). It should be noted that while the overall impact of incidents may be small for the nation as a whole, any hazardous material spill may have severe impacts on flora and fauna in the location of occurrence.

FACTORS THAT AFFECT IMPACT

- Quantity of hazardous materials transported and distance transported
- Accident or spill rate
- Type (toxicity/hazard) and quantity of materials spilled
- Effectiveness of cleanup efforts
- Population density
- Sensitivity of local habitats/species

INDICATORS OF ENVIRONMENTAL IMPACT

No statistics were found regarding the number of species or acres nationwide affected by commodity spills or other hazardous materials incidents.

The Hazardous Materials Information System (HMIS) database, maintained by U.S. DOT/RSPA, contains a record of all reported hazardous materials incidents occurring during truck transport (except for intrastate only operators), including type of material spilled, number of injuries/fatalities, and estimated clean up costs.

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[16] U.S. Department of Transportation, Bureau of Transportation Statistics. *National Transportation Statistics 1998.* January 1999 (Table 1-11). www.bts.gov/btsprod/nts

[17] Atkinson, Robert B. and John Cairns, Jr. "Ecological Risks of Highways." In *Predicting Ecosystem Risk.* 1992.

Table 3-39: Highway Hazardous Materials Incident Totals, 1990-1997

Year	Number of Incidents	Gallons Released	Pounds Released	Cubic Feet Released	MilliCuries Released+	Clean Up & Product Loss Damages
1990	7,114	668,673.63	368,353.72	309,762.16	90.00	$9,637,302
1991	7,479	671,966.94	318,678.13	120,253.88	4.60	$10,990,231
1992	7,589	748,897.25	157,324.47	1,427,325.80	0	$14,148,560
1993	10,731	620,492.88	302,567.03	17,414.66	0	$11,060,161
1994	13,559	535,270.88	295,335.72	1,478.37	0	$12,224,619
1995	12,505	555,598.31	214,583.69	56,019.01	100,002.40	$12,285,402
1996	11,662	706,547.06	279,532.19	127,217.80	0	$13,978,567
1997	11,603	629,638.50	334,787.63	9,386.53	0.10	$12,714,625

* Due to multiple classes being involved in a single incident, the totals above may not correspond to the totals in other reports. + MilliCuries (mCi) are a measure of radioactivity.
Source: U.S. Department of Transportation, Research & Special Programs Administration (RSPA). *Hazardous Materials Information System.*

Figure 3-14: Highway Hazardous Materials Incidents, 1990-1997

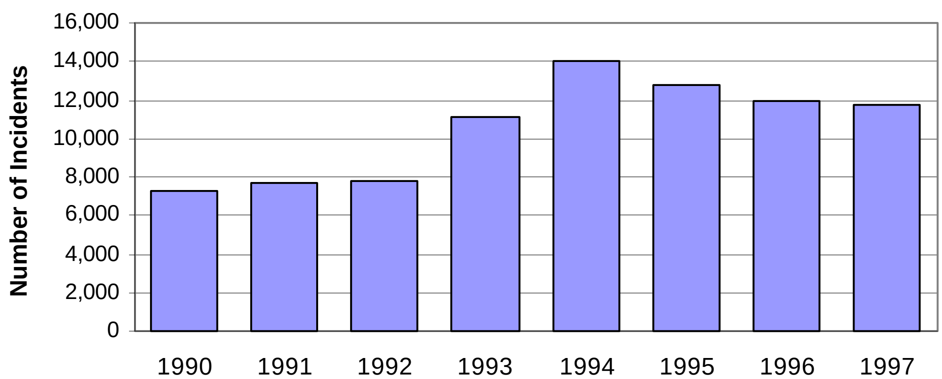

Table 3-40: Highway Hazardous Materials Incidents, 1997

Hazard Class	Number of Incidents*	Gallons Released	Pounds Released	Cubic Feet Released	MiliCuries Released+	Clean Up & Product Loss Damages
Corrosive Material	4,755	76,898.59	1,668.31	0	0	$2,166,970
Flammable - Combustible Liquid	4,711	403,180.56	8	0.13	0	$5,787,535
Poisonous Materials	923	4,337.93	1,654.14	0	0	$897,872
Oxidizer	377	6,752.97	143,042.52	0	0	$458,632
Miscellaneous Hazardous Material	371	70,792.37	139,023.16	0	0	$999,760
Combustible Liquid	278	38,439.23	0	0	0	$389,102
Nonflammable Compressed Gas	123	14,416.63	222.13	2,242.01	0	$210,898
Flammable Gas	101	5,613.64	0	7,024.08	0	$279,321
Organic Peroxide	96	224.82	19.45	0	0	$47,399
Flammable Solid	87	3,000.28	2,270.45	0	0	$88,732
Poisonous Gas	29	552.37	0	120.31	0	$82,701
Spontaneously Combustible	15	144.01	186.56	0	0	$771,210
Dangerous When Wet Material	15	240.13	45,725.94	0	0	$305,901
Radioactive Material	1	0	0	0	0.10	$8,000
Very Insensitive Explosive	4	0.63	932	0	0	$840
Infectious Substance (Etiologic)	4	0.13	0	0	0	$2
Other Regulated Material, Class D	1	17.88	0	0	0	$3,684
Explosive Mass Explosion Hazard	1	0	35	0	0	$0
Explosive Projection Hazard	1	5,020.25	0	0	0	$216,066
Explosive No Blast Hazard	1	0	0	0	0	$0
Forbidden	0	0	0	0	0	$0
Explosive Fire Hazard	0	0	0	0	0	$0
Extremely Insensitive Detonating	0	0	0	0	0	$0
Explosives, Class A	0	0	0	0	0	$0
Explosives, Class B	0	0	0	0	0	$0
Explosives, Class C	0	0	0	0	0	$0
Flammable Solid (Pre 1991)	0	0	0	0	0	$0
Irritating Material	0	0	0	0	0	$0
Other Regulated Material, Class A	0	0	0	0	0	$0
Other Regulated Material, Class B	0	0	0	0	0	$0
Other Regulated Material, Class C	0	0	0	0	0	$0
Other Regulated Material, Class E	0	0	0	0	0	$0
TOTALS	**11,603**	**629,638.50**	**334,787.63**	**9,386.53**	**0.10**	**$12,714,625**

* Includes only those incidents for which quantities of HazMat releases are known.
+ MilliCuries (mCi) are a measure of radioactivity.

Note: The total number of incidents is not equal to the sum of incidents by hazard class, because one incident may be reported under two or more hazard classes.

Source: U.S. Department of Transportation, Research & Special Programs Administration (RSPA). *Hazardous Materials Information System.*

COLLISIONS WITH WILDLIFE

DESCRIPTION OF IMPACT

Vehicle collisions with wildlife are a concern because of the loss of animal life, damage to property, and injuries and fatalities for vehicle drivers and passengers. Although few national composite figures are available, many states track the number of animal-related incidents on their major roadways. The Highway Safety Information System (HSIS) tracks motor vehicle crashes and their cause in eight states — California, Illinois, Maine, Michigan, Minnesota, North Carolina, Washington, and Utah — and is a source of information on wildlife collisions.

Roads passing through wildlife habitat are a threat to wildlife, especially in the first several years after a new road is constructed. It may take several years for wildlife to adapt to changes such as a new roadway in their habitat. As a result, road mileage may have a significant impact on wildlife strikes, and may be a more important factor than the amount of vehicle travel. Vehicle miles of travel (VMT) likely has some relationship to wildlife strikes, but the exact nature of that relationship is unclear. In the case of a new road, the introduction of "new" VMT into a region generally results in increased strikes. Once the habitat adapts to the presence of the road, however, the impact of increased VMT is less clear. The size of the animal population in a given area is also a primary determinant of wildlife collisions.

There is little consensus regarding the most effective means of preventing collisions with wildlife. Wildlife often manages to circumvent protective fencing by jumping over, going around, or going through open gates and holes. Reflectors, lighting, underpasses dedicated to wildlife, mirrors and signage have been shown by some studies to be relatively ineffective at changing the behavior of both drivers and wildlife.[18]

FACTORS THAT AFFECT IMPACT

- Habitat fragmentation, barriers to crossing formed by roads
- Lack of driver education on wildlife hazards and alertness
- Gaps in barriers and fences due to human activities
- Distance between edge of road and forest/vegetation
- Visibility (alignment, lighting, etc.)
- Location of road relative to wildlife habitat (urban/ rural)

INDICATORS OF ENVIRONMENTAL IMPACT

NUMBER OF ANIMALS KILLED

In the United States, roadkill losses are estimated to be at least 1 million animals per day due to conflict with traffic while crossing roads

Source: Tolley, R.S. and B.J. Turton. *Transport Systems, Policy and Planning: A Geographic Approach.* Longman Scientific and Technical. 1995.

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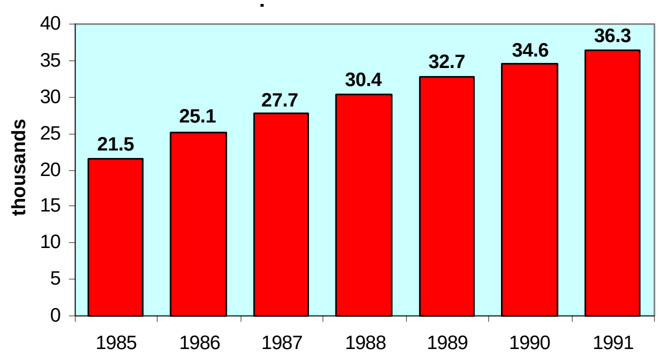
[18] Fornwalt, et al., 1980; Colorado Division of Wildlife, 1980; California Department of Transportation, 1980; Lehtimaki, 1981.

A total of approximately 208,300 wildlife collisions with motor vehicles were reported in the Highway Safety Information System (HSIS) for 1985 to 1991 in five states — Illinois, Maine, Minnesota, Utah, and Michigan. Data from the five states shows a 69 percent increase in reported animal collisions over the 7-year period, from 21,479 in 1985 to 36,332 in 1991. The figure below shows the trend in the number of animal crashes.

Figure 3-15: Animal Collisions with Motor Vehicles



Although some crashes involved domestic animals, states that reported the type of animal involved in the crash found that most reported animal crashes involved deer. In Michigan, almost all the hit-animal crashes (99.7 percent) were deer related, and data from Minnesota indicate that over 90 percent of animal crashes involved deer. The greatest number of animal crashes by far occurred in November, which is the mating season for deer. The crash rate is substantially higher on two-lane rural roads than on urban roads; for the five states reporting to HSIS, 66 percent of animal crashes occurred on two-lane rural roads.

Source: U.S. Department of Transportation, Federal Highway Administration, Turner-Fairbanks Highway Research Center. "HSIS Summary Reports: Investigation of Crashes with Animals." March 1995 (FHWA-RD-94-156). http://tfhrc.gov/hsis/94-156.htm.

3.4 MAINTENANCE, SUPPORT, AND OPERATIONS

Operation and maintenance of highways involves various activities, such as application of de-icing chemicals and pesticides. Vehicle maintenance and support facilities include motor freight terminals, bus yards, fuel storage tanks, and auto fueling and service stations, all of which have associated environmental impacts.

HIGHWAY OPERATIONS AND MAINTENANCE

DESCRIPTION OF IMPACT

Highway operations and maintenance involve activities such as painting of bridges, re-striping of highways, de-icing of roadway facilities during winter weather conditions, and application of pesticides to roadside vegetation. Each of these activities is associated with potentially harmful environmental impacts, as shown in the text box below:

CONTAMINATION ENCOUNTERED IN HIGHWAY OPERATIONS AND MAINTENANCE
(NCHRP, 1993; based on telephone survey of 16 states[19])

- **Lead Paint**: All states reported that lead paint residues from bridges were a problem.
- **Solvents and Pesticides**: Four states had significant problems with solvents and pesticides at maintenance yards and with solvents as laboratory wastes, from asphalts in particular.
- **Salt**: Two states had problems with salt runoff from maintenance stockpiles contaminating groundwater.
- **General Maintenance**: Six states volunteered that they had problems at their maintenance facilities.

Deicing is a significant contributor to highway runoff problems, particularly in northern states where cold weather necessitates greater use of de-icing chemicals. Rock salt is the principal deicing agent used in winter road maintenance throughout the nation.

The use of road salt allows highway travel during snow conditions and is important for delivery of vital goods and services (including emergency support vehicles which save lives) to large segments of the country. Although salt is cheap and effective, it can cause adverse environmental effects. Environmental impacts of road salt include effects on roadside vegetation, harm to soil structure, and impacts on drinking water and aquatic life.[20] The effect of deicing runoff is not limited to roadside vegetation: 90% of the salt applied to the street of Buffalo, NY, for example, enters into the city sewerage system and then reaches Lake Ontario.[21]

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[19] States surveyed: AK, AZ, FL, IL, LA, MN, MO, MT, NH, NY, OR, PA, TN, TX, VA, WA.

[20] Transportation Research Board, National Research Council. *Highway Deicing: Comparing Salt and Calcium Magnesium Acetate.* Special Report 235, 1991.

[21] Tolley, R.S. and B.J. Turton. *Transport Systems, Policy and Planning: A Geographic Approach.* Longman Scientific and Technical. 1995.

FACTORS THAT AFFECT IMPACT

The actual extent of water contamination and habitat alteration arising from road salt use depends on highly site-specific conditions such as watershed characteristics, amount of runoff and/or snowmelt, and type of indigenous vegetation:

- Amount of roadway deicing agent applied
- Type of deicing agent used
- Climate/weather conditions (amount of snow, ice, rainfall)
- Amount of high salinity runoff/snowmelt that reaches bodies of water (based on runoff controls and local geography)
- Depth of groundwater table
- Sensitivity of nearby habitats

INDICATORS OF ENVIRONMENTAL IMPACT

ROAD SALTING

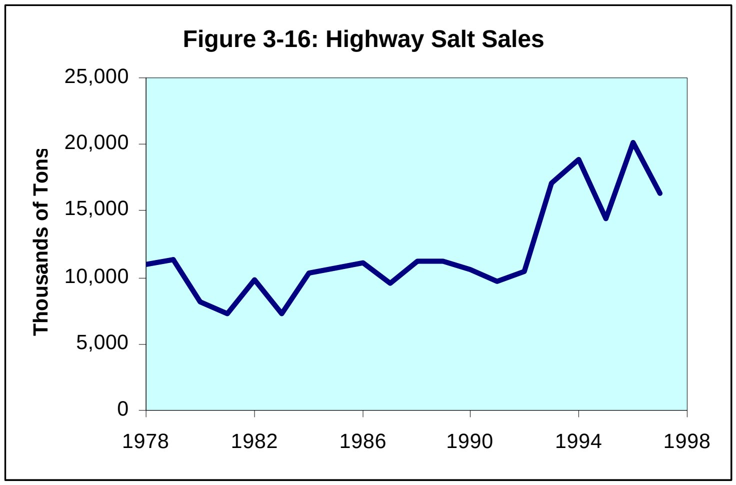
Specific outcomes, including wildlife habitat damage, reduced fish stocks, loss of unique natural features, and corrosion damage to vehicles from increased salinity, are not quantified nationally and no quantified data are available to estimate how much road salt enters groundwater, rivers, and lakes. Some information about impacts are known:

> Typically, 5-10% of trees along heavily traveled roads are affected by road salt application. Salting of a typical road could kill 1 to 25 roadside trees per year, depending on salt application rates and roadway proximity to trees.
>
> Source: Transportation Research Board, National Research Council. *Highway Deicing: Comparing Salt and Calcium Magnesium Acetate.* Special Report 235, 1991.
>
> In 1996, 3 states, compared to 4 states in 1994, reported wetlands impacts from salinity.
>
> Source: U.S. Environmental Protection Agency. *Appendices from the National Water Quality Inventory: 1996 Report to Congress*. www.epa.gov/OW/resources

In the past decade, 10 million tons of salt have been applied in a typical year, but applications from 1993 onwards have been significantly higher.

Table 3-41: Highway Salt Sales, 1970-1997

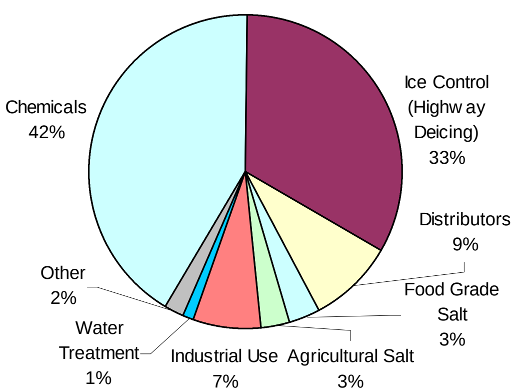
Year	Tons (000)
1978	10,927
1979	11,323
1980	8,108
1985	10,730
1986	11,057
1987	9,573
1988	11,202
1989	11,227
1990	10,528
1991	9,730
1992	10,457
1993	17,126
1994	18,885
1995	14,427
1996	20,117
1997	16,369



Source: Salt Institute, 1998. http://www.saltinstitute.org/33.html#highways

Nationally, road salt for ice control comprises about one-third of total salt use for all purposes.

Figure 3-17: Uses of Salt in the U.S., 1996



Source: U.S. Geological Survey. "Salt." *Minerals Information, 1996.* http://minerals.er.usgs.gov/minerals/pubs/commodity/salt/580496.pdf

MOTOR FREIGHT TERMINAL OPERATIONS: TANK TRUCK CLEANING, MAINTENANCE, AND REPAIR

DESCRIPTION OF IMPACT

Motor freight terminal operations include short and long haul truck activities (such as tank car unloading and cleaning), furnishing of terminal facilities for passenger or freight traffic, and cleaning and maintenance functions including equipment degreasing, exterior washing, and painting. Many of these processes use materials that are hazardous or may in turn generate hazardous waste or wastewater. In addition, refueling operations impact the environment through spills, and through fuel tank vapors that are displaced when the tank is filled with liquid fuel. The actual impact of terminal activities on the environment depends on the type and volume of operations, levels of cleanliness, the type of wastes generated, and wastewater treatment systems in place.

Table 3-42: Typical Motor Freight Terminal Operations: Materials Used and Types of Waste Possibly Generated

Process/Operation	Materials Used	Types of Waste/Emissions
Unloading or Cleaning of Tank Cars	Solvents, alkaline cleaners	VOC Emissions Acid/alkaline wastes Toxic wastes Solvent wastes Residual tank contents
Rust Removal	Naval jelly, strong acids, strong alkalis	Acid/alkaline wastes
Painting	Enamels, lacquers, epoxies, alkyds, acrylics, primers, solvents	VOC Emissions Ignitable wastes Toxic wastes Paint wastes Solvent wastes
Paint Removal	Solvents, paint thinners, enamel, white spirits	Paint wastes Toxic wastes Solvent wastes
Exterior Washing	Solvents, cleaning solutions	VOC Emissions Solvent wastes Oil and grease
Equipment degreasing	Degreasers, engine cleaners, acids, alkalis, cleaning fluids	Ignitable waste Combustible solids Acid/alkaline wastes
Refueling	Gasoline, diesel fuel	Evaporative losses - VOCs Fuel drips and spills
Changing of batteries	Lead-acid batteries	Acid/alkaline wastes Batteries (lead acid)

Source: U.S. Environmental Protection Agency/RCRA Fact Sheet: Motor Freight/Railroad Terminal Operations, 1993. U.S. Environmental Protection Agency. *Profile of the Transportation Equipment Cleaning Industry.* 1995.

An important component of the transportation equipment cleaning industry is the cleaning of tank truck interiors. Although most truck tanks are in dedicated service (carrying only one commodity), many must be cleaned after every trip to prevent contamination of materials. A typical tank truck car has a volume of 3,500 to 8,000 gallons and generates about 500 to 1,000 gallons of wastewater during cleaning, resulting in the output of spent cleaning fluids, fugitive VOC emissions, water treatment system sludge, and tank residues. The disposal and treatment of tank heels can also be source of pollution for tank cleaning facilities. The typical heel volume of a tank truck car is 5 - 10 gallons per tank, and a facility’s wastewater treatment system may be adversely affected by, or may not adequately treat, a slug of concentrated tank residue. Incompatible heels are usually segregated and resold to a reclaimer or shipped off-site for disposal. Heels that are composed of detergents, solvents, acids, or alkalis can be stored on-site and used as a tank cleaning fluid or to neutralize other tank heels. There are 1,841 truck/land tank cleaning facilities in the U.S.[22]

Approximately 90% of transportation equipment cleaning facilities discharge wastewater to publicly owned treatment works or combined treatment works (privately owned by multiple facilities) after some amount of treatment. Some facilities discharge directly to surface waters under the National Pollution Discharge Elimination System (NPDES) permits or to underground injection wells under Safe Drinking Water Act permits. Allowable emissions could be tracked based on these permits, although actual emissions may vary.

FACTORS THAT AFFECT IMPACT

- Number of terminals
- Type and level of terminal operations
- Materials used during terminal operations
- Wastewater treatment capabilities

INDICATORS OF ENVIRONMENTAL IMPACT

Data on water quality impacts to streams, rivers, and lakes, and related habitat due to tank truck terminal operations are not available. Data on health effects from air pollution coming from terminals are also not available. National statistics are not readily available, although EPA's MOBILE model produces emissions factors for hydrocarbons due to refueling on a per mile basis.

WASTEWATER FROM BUS WASHING

75 percent of transit agencies surveyed collect and treat wastewater from bus washing operations. 65% of transit agencies wash their active bus fleets daily during summer months. 81% wash daily during the winter.

Source: Based on survey of TCRP survey (1995) of 120 geographically diverse transit agencies in the U.S. and Canada; 52 respondents. Transit Cooperative Research Program. *Transit Bus Service Line and Cleaning Functions.* 1995.

VOC EMISSIONS

Tank car and rail car cleaning operations emit 1.25 million pounds of VOCs per year. Data on other wastes generated from motor freight terminal operations have not been estimated at the national level.

Source: U.S. Environmental Protection Agency. *Profile of the Transportation Equipment Cleaning Industry.* 1995.

[22] Land facilities are those that clean any combination of the following equipment: tank trucks, rail tank cars, intermediate bulk carriers, intermodal tank containers. U.S. Environmental Protection Agency. *Profile of the Transportation Equipment Cleaning Industry.* 1995 (p. 7).

SERVICE STATIONS: PASSENGER VEHICLE CLEANING, MAINTENANCE, REPAIR, AND REFUELING

DESCRIPTION OF IMPACT

Facilities such as gas stations, maintenance shops, and service stations impact the environment through runoff of gas, oil, and dirt; waste releases to sewer systems; air emissions; and waste disposal. Fueling activities generate air emissions due to VOC losses during transfer. There are two types of refueling losses: “stage one” are losses associated with the refilling of underground storage tanks, and “stage two” occur during the transfer of fuel from pump to automobile gas tank. Both stage one and stage two losses are counted as stationary source emissions by EPA’s Office of Air Quality Planning and Standards.

Relatively small amounts of waste and wastewater are generated from the washing, maintenance, and painting of motor vehicle exteriors. Typical hazardous wastes generated include spent solvents, spent caustics, strippers, paint chips, and paint sludges. Wastewater is generally treated on-site and then discharged to a public treatment works.

FACTORS THAT AFFECT IMPACT

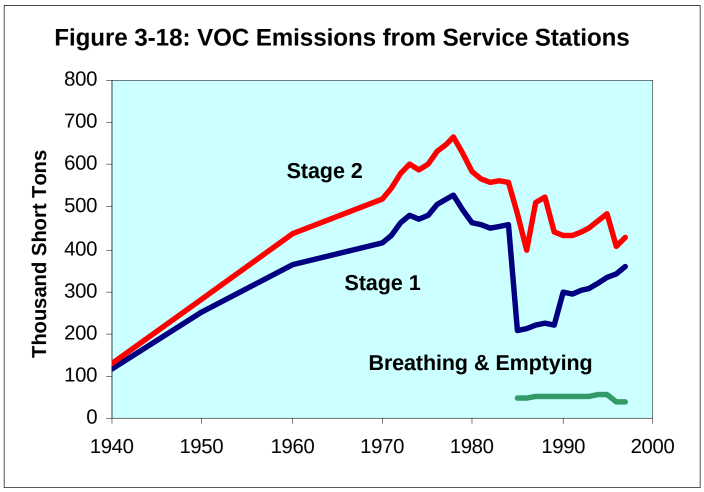
- Number of maintenance facilities
- Type and level of maintenance operations
- Materials used during maintenance operations
- Wastewater treatment capabilities

INDICATORS OF ENVIRONMENTAL IMPACTS

EMISSIONS FROM RELEASES OF FUEL AT SERVICE STATIONS

Table 3-43: VOC Emissions from Service Stations, 1940-1997

Year	Service Stations: Stage I	Service Stations: Stage II	Service Stations: Breathing & Emptying
1940	117	130	NA
1950	251	283	NA
1960	365	437	NA
1970	416	521	NA
1980	461	583	NA
1985	207	485	49
1990	300	433	52
1991	295	430	51
1992	303	442	52
1993	309	449	53
1994	322	467	55
1995	334	484	57
1996	341	406	37
1997	359	427	39



Source: U.S. Environmental Protection Agency. *National Air Pollutant Emissions Trends Report, 1900-1997* (Table A-3).

LEAKING UNDERGROUND STORAGE TANKS (USTs) CONTAINING FUEL

DESCRIPTION OF IMPACT

Underground storage tanks (USTs) are used to store fuel at gas stations and other facilities, as well as other chemicals. Leaking petroleum USTs can be a major source of groundwater contamination. Releases from tanks and piping occur from corrosion of older, unprotected steel tanks and piping, or from cracks in tanks made from other materials. Overfilling and spillage during refueling are also responsible for accidental releases. The UST regulations that EPA issued in 1988 established a number of corrective action requirements for UST owners and operators, including the requirement to clean up soil and groundwater as needed to protect human health and the environment. EPA regulations required that by 1998 all existing USTs have spill protection through catchment basins, automatic shutoff devices, overfill alarms, and mandatory corrosion protection for steel tanks and piping.

FACTORS THAT AFFECT IMPACT

- Number of leaking underground storage tanks (USTs)
- Type and quantity of materials released from leaking USTs
- Spill protection mechanisms
- Cleanup efforts initiated and completed
- Location of groundwater table
- Sensitivity of local ecosystems
- Treatment of drinking water

INDICATORS OF ENVIRONMENTAL IMPACT

As a result of these stringent regulations, there has been a decrease in the number of active petroleum USTs in the U.S. as petroleum UST systems have been closed. Data on number of active tanks and the cumulative number of closed tanks, releases reported, cleanups initiated and completed, and emergency responses are compiled in EPA's Corrective Action Measures reports (formerly called "STARS", Strategic Targeted Activities for Results System).

Table 3-44: Corrective Action Measures Reports for the U.S., 1996 - 1998

Time Period	# Active Tanks	Tanks Closed*	Confirmed Releases*	Cleanups Initiated*	Cleanups Completed*
1st Half FY 1996	1,093,018	1,043,437	314,720	241,787	141,185
2nd Half FY 1996	1,064,478	1,074,022	317,488	252,615	152,683
1st Half FY 1997	1,031,960	1,111,266	329,940	276,603	162,431
2nd Half FY 1997	969,652	1,150,824	341,773	292,446	178,297
1st Half FY 1998	919,540	1,186,341	358,269	301,842	192,065
2nd Half FY 1998	891,686	1,236,007	371,387	314,965	203,247

*Cumulative

Source: U.S. Environmental Protection Agency, Office of Underground Storage Tanks. "Corrective Actions Measures Archive." http://www.epa.gov/swerust1/cat/camarchv.htm

3.5 DISPOSAL OF VEHICLES AND PARTS

Motor vehicle disposal is the last phase in the lifecycle analysis of highway-related environmental impacts. Dismantling operations involve both automotive fluids and solids. Fluids, such as engine oil, antifreeze, and air conditioning refrigerant, are recovered to the extent possible and reprocessed for reuse or sent to energy recovery facilities. Many solid parts, such as radiators and catalytic converters contain valuable metal materials, which are removed for recycling or reuse. In addition, the dismantler will remove and recycle the battery, fuel tank, and tires to reduce shredder processing concerns.

SCRAPPAGE OF VEHICLES

DESCRIPTION OF IMPACT

There are an estimated 12,000 automobile scrappage/disassembly operations in the United States. When a vehicle is dismantled, fluids, including oil, antifreeze, and refrigerant, are drained and removed. Solid parts such as the radiator and catalytic converter are removed for recycling or reuse. The battery, fuel tank, and tires are also separated. If undamaged, parts are cleaned, tested, inventoried, and sold, and if damaged, are recycled with similar materials.

The remaining hulk is then flattened and shredded at one of the 200 shredding operations in North America and sorted into ferrous, nonferrous (8.7% of the whole vehicle), and residual components. The residue contains plastics, glass, textiles, metal fines, and dirt, which are generally all landfilled.

FACTORS THAT AFFECT IMPACT

- Number of vehicles scrapped
- Fraction disposed of properly (through recycling, recovery, etc.)
- Use of hazardous materials in vehicles
- Recovery rate of materials in scrapped vehicles

INDICATORS OF ENVIRONMENTAL IMPACT

Estimates are not available on the health and environmental impacts of landfilling or other disposal of scrapped vehicles.

VEHICLES SCRAPPED PER YEAR

Approximately 11.3 million motor vehicles were scrapped in 1996. Trends are shown below.

Table 3-45: Motor Vehicle Scrapped Annually* (thousands)

Year	Passenger Cars	Trucks	Motor Vehicles, total
1970	7,461	837	**8,298**
1975	5,669	908	**6,577**
1980	8,405	1,732	**10,137**
1985	7,729	2,100	**9,829**
1990	8,897	2,177	**11,074**
1991	8,565	2,284	**10,849**
1992	11,194	1,587	**12,781**
1993	7,366	1,048	**8,414**
1994	7,824	4,545	**12,369**
1995	7,414	2,918	**10,332**
1996	7,527	3,864	**11,391**

*Note: Figures represent vehicles that are not reregistered. Estimates July 1 to June 30 (e.g., 1970 data is from July 1, 1969 to June 30, 1970)

Source: U.S. Department of Transportation, Bureau of Transportation Statistics. *National Transportation Statistics 1998.* Table 4-45.

RECYCLING OF SCRAPPED VEHICLES

The U.S. boasts one of the most effective and prosperous vehicle recycling industries in the world. Approximately 94% of all scrapped vehicles are collected and recycled annually at one of the 12,000 scrappage/disassembly locations in the U.S.

At least 75% of the material collected from scrapped vehicles (steel, aluminum, copper) is recycled for raw material use, and 25% landfilled. This effort is estimated to result in approximately 11 million tons of recycled steel and 800,000 tons of recycled nonferrous metals, saving an estimated 85 million barrels of oil that would be used to manufacture new parts. Scrap vehicle waste comprises about 1.5% of total municipal landfill waste.

Source: U.S. Environmental Protection Agency. *Profile of the Motor Vehicle Assembly Industry*. EPA Office of Compliance Sector Notebook Project, September 1995.

MOTOR OIL DISPOSAL

DESCRIPTION OF IMPACT

Used motor oil contains high concentrations of detergents, metals, and other toxics. These materials degrade water quality when improperly disposed. One quart of used oil is enough to contaminate a million gallons of fresh water.

FACTORS THAT AFFECT IMPACT

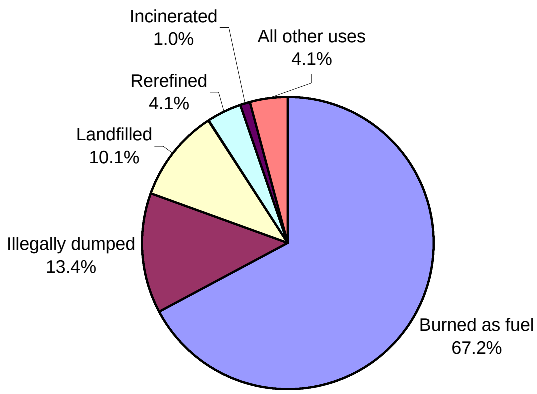
- Quantity of oil used in motor vehicle operations.

- Recovery rate
- Groundwater contamination and seepage prevention measures at the disposal site
- Sensitivity of local ecosystems
- Water treatment technologies

INDICATORS OF ENVIRONMENTAL IMPACT

13 percent, or 185 million gallons, of all used oil is illegally dumped; a further 10 percent, or 140 million gallons, of all used oil is landfilled.

Figure 3-19: Disposal of Used Oil, 1991



Source: OSW Data, by Clayton Envir. Consultants, Lexington, MA, 1992. Referenced by: U.S. Environmental Protection Agency. *Municipal Solid Waste Factbook--Internet Version.* http://www.epa.gov/epaoswer/non-hw/muncpl/factbook/internet/mswf/

TIRE DISPOSAL

DESCRIPTION OF IMPACT

Disposal of used tires from motor vehicles can pollute sewers, wastewater treatment plants, and groundwater supplies, as well as take up landfill capacity. Many landfills do not allow tire disposal because tires decompose extremely slowly; they collect gases released by decomposing garbage, and then gradually float up to the surface of the landfill. In addition, used tires contain oil, making them a fire hazard, and may retain stagnant water, an ideal breeding ground for mosquitoes.

Tires pose a considerable fire hazard and once ignited they can emit toxic gases, such as polyaromatic hydrocarbons, CO, SO_2, NO_2 and HCl. The use of water to extinguish tire fires can result in soil and water contamination from oils generated by the burning tires. Furthermore, these fires can be extremely difficult to extinguish. Stockpiles of tires have been known to burn continuously for more than a year.[23]

FACTORS THAT AFFECT IMPACT

- Quantity of tires disposed (based on number of vehicles, vehicle miles of travel, and tire service life)
- Recovery rate
- Method of disposal or recycling
- Proximity to human population or habitat
- Toxic constituents in tires

INDICATORS OF ENVIRONMENTAL IMPACT

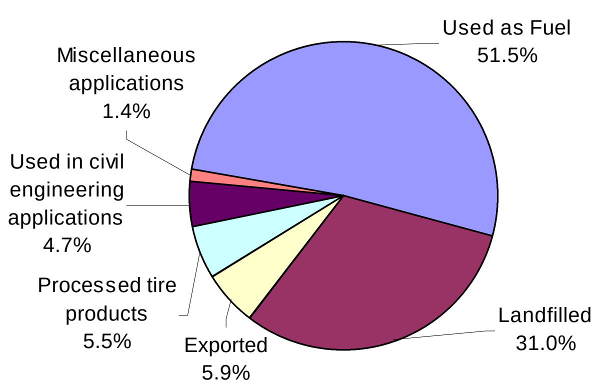
Statistics are not available on the amount of groundwater contamination, air pollution, or other environmental outcomes specifically attributable to disposal of tires from motor vehicles.

TIRE SCRAPPAGE TREND

In 1996, 266 million tires were scrapped, a 5.5% increase since 1995, with 76% recovered (202 million) compared to 69% recovered (174.5 million) in 1995. Recovery includes removal of tires from the municipal waste stream through recycling, use as fuel, and net exports of material. About 75.5% of those recovered were burned as tire-derived fuel. In the early 1990s, by contrast, 242 million tires were scrapped annually, with only a 30% recovery rate, leaving 169 million tires to be landfilled or stockpiled each year.

Sources: Scrap Tire Management Council: http://www.rma.org.
U.S. Environmental Protection Agency. *Your Car (or Truck) and the Environment.* 1993.

Figure 3-20: Disposition of Scrap Tires, 1995



Source: Source: Resource Recycling, March 1996. Referenced by: U.S. Environmental Protection Agency. *Municipal Solid Waste Factbook--Internet Version.* http://www.epa.gov/epaoswer/non-hw/muncpl/factbook/internet/mswf/

[23] U.S. Environmental Protection Agency. *Markets for Scrap Tires.* October 1991.

The amount of tires being recycled or recovered for uses such as highway construction or insulation has risen since the 1980s.

Table 3-46: Rubber Tires in Municipal Solid Waste Stream, 1960 - 1996

Year	Waste Generation (thousands of tons)	Recycling of Products (thousands of tons)	Percent recycled
1960	1,120	330	29.5%
1970	1,890	250	13.2%
1980	2,720	150	5.5%
1990	3,610	440	12.2%
1992	3,610	470	13.0%
1994	4,080	620	15.2%
1995	3,770	660	17.5%
1996	3,910	730	18.7%

Source: U.S. Environmental Protection Agency. *Characterization of Municipal Solid Waste in the United States: 1997 Update.* Prepared by Franklin Associates, Ltd. May 1998. Tables 12 and 13. www.epa.gov/epaoswer/non-hw/muncpl/mswrpt97/msw97re.pdf

AIR EMISSIONS

Waste tire incineration was responsible for approximately 2 pounds of polychlorinated biphenyl (PCB) emissions out of total national emissions of 282 pounds in 1990. Since 1990, the rate of tire incineration has increased dramatically.

Source: U.S. Environmental Protection Agency. *National Air Pollutant Emission Trends, 1990-1994.* 1995.

TIRES IN STOCKPILES

Approximately 800 million used tires remain stockpiled in the U.S.

Source: Hilts, Michael. "Broadening the Market for Scrap Tire Rubber." *Solid Waste Technologies,* 10(1): 14-19. January/February 1996.

LEAD-ACID BATTERY DISPOSAL

DESCRIPTION OF IMPACT

The average passenger vehicle battery has a useful life of three to four years, and contains 18 pounds of lead, 2 pounds of plastic, and about a gallon of sulfuric acid. Improper disposal of used batteries can cause environmental problems because lead is a hazardous material and lead from landfilled batteries can leach into groundwater or contaminate surrounding soil.

Over 90 percent of spent lead-acid batteries are recycled for use in the production of new batteries. The typical new lead-acid battery contains 60 to 80 percent recycled lead and plastic.[24]

[24] Battery Council International, web site http://www.batterycouncil.org/recycling.html accessed July 30, 1999.

When a spent battery is collected, it is sent to an authorized recycler where the lead and plastic are reclaimed and sent to a new battery manufacturer. Despite the high rate of recycling, lead-acid batteries, primarily from automobiles, remain the largest source of lead entering the waste stream. It is estimated that lead from automotive batteries accounts for about two-thirds of the lead (by weight) in municipal solid waste sites.[25]

FACTORS THAT AFFECT IMPACT

- Quantity of batteries used in motor vehicle operations (based on number of motor vehicles, number of vehicle trips, and battery life)
- Recovery rate
- Groundwater contamination and seepage prevention measures at the disposal site
- Proximity to human population or habitat

INDICATORS OF ENVIRONMENTAL IMPACT

Statistics are not available on the amount of groundwater contamination or other environmental outcomes specifically attributable to disposal of batteries, or on discharge of toxics from the disposal of lead-acid batteries. Since recycling rates for lead-acid batteries are very high, the impacts are likely to be small.

QUANTITY OF USED LEAD ACID BATTERIES

In 1995, an estimated 0.9 million tons of lead were generated from spent automotive lead-acid batteries. However, 89.5% of all lead available for recycling (from all sources) was recovered and recycled nationwide.

Source: National Recycling Rate Study, Smith, Bucklin and Associates, Inc. 1996.

Table 3-47: Lead Acid Batteries in Municipal Solid Waste Stream, 1960 - 1996

Year	Waste Generation (thousands of tons)	Recycling of Products (thousands of tons)	Percent recycled
1960	Neg.	Neg.	-
1970	820	620	75.6%
1980	1,490	1,040	69.8%
1990	1,510	1,480	98.0%
1992	1,530	1,450	94.8%
1994	2,010	1,980	98.5%
1995	1,810	1,620	89.5%
1996	1,810	1,700	93.9%

Source: U.S. Environmental Protection Agency. *Characterization of Municipal Solid Waste in the United States: 1997 Update.* Prepared by Franklin Associates, Ltd. May 1998. Tables 13 and 14.

[25] Kreith, F. ed. *Handbook of Solid Waste Management.* New York, NY: McGraw-Hill, Inc., 1994.

4. RAIL ENVIRONMENTAL INDICATORS

This chapter describes environmental impacts of rail transportation and presents quantitative indicators available for tracking the nationwide environmental impacts of rail. Rail transportation is defined here to encompass freight transportation and both intercity (Amtrak) and intracity passenger rail. Intracity passenger rail includes heavy-rail (subways and elevated systems), light-rail, and commuter-rail service. Impacts are described for five categories of rail activities:

- Railroad Construction and Abandonment
- Rail Equipment Manufacture
- Rail Travel
- Rail Operations, Maintenance, and Support
- Disposal of Rail Cars and Parts

4.1 RAILROAD CONSTRUCTION AND ABANDONMENT

Railroad construction and maintenance activities can result in a number of adverse environmental effects. Construction activities can cause temporary environmental impacts such as air pollutant emissions and noise from construction equipment, erosion, and/or solid waste impacts. Infrastructure development may also have long term environmental consequences, including habitat disruption and hydrologic alterations.

HABITAT AND LAND USE

DESCRIPTION OF IMPACTS

The addition of new railway infrastructure involves taking land in the right-of-way, which can fragment habitat and affect both flora and fauna over the long-term. The average width of land occupied by a railway track and buffer zone, however, is only about 0.016 miles (25 meters), resulting in a small amount of direct land usage.[1] The linear nature of railway lines leads to the splitting of natural habitats, possibly decreasing habitat size and reducing interaction between communities of species. Railway structures may damage existing vegetation, interfere with wildlife crossings, displace communities of animals and birds, and alter the hydrology of areas they pass through. Existing rail mileage consists of approximately 177,000 miles of track, of which 168,964 miles are owned and operated by freight railroads; Amtrak operates over 23,750 route miles on track owned by freight railroads and 750 miles of track that Amtrak owns.[2]

Over time, rail right-of-way can protect habitats from development and certain species may become accustomed to nesting along the right-of-way. When rail lines are abandoned, salvage activities (such as the removal of track, bridges, or culverts) may cause habitat disruption. As a result, rail abandonment can also create environmental issues. The Surface Transportation Board (STB) approved 1,253 miles of abandonments in FY1997 and 2,245 miles of abandonments in FY1997.[3]

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[1] Carpenter, T.G. *The Environmental Impact of Railways.* John Wiley & Sons. 1994.
[2] Association of American Railroads. www.aar.org, as cited February 14, 1999.
[3] Surface Transportation Board, *1996/1997 Annual Report*

Railway construction or salvage activities may have temporary, but significant, environmental impacts due to drilling and excavation activities, disposal of excess material, and discovery of hazardous material in the right-of-way. Some heavy-rail systems have been constructed underground as subways, either through cut-and-cover methods or tunneling. While subways typically are built in highly urban areas, this construction may still have environmental impacts related to drainage, soils, and geology.

Measures can be taken, however, to mitigate environmental damage, such as route selection to bypass particularly sensitive areas, compensatory habitat creation and relocation, fine adjustments to vertical or horizontal alignments, and limiting salvage and construction activities to certain times and locations. In FY1997, the Surface Transportation Board's Section on Environmental Analysis conducted 125 Environmental Assessments involving railroad abandonments as well as analyzing construction proposals in Alabama, Louisiana, Nebraska and South Dakota. Mitigation measures imposed often involve the protection of critical habitats for threatened and endangered species, historic and cultural resources, and wetlands.[4]

FACTORS THAT AFFECT IMPACT

- Miles of track constructed/tons of new rail laid
- Miles of track abandoned and/or salvaged
- Type of construction (elevated, at-grade, underground)
- Ecological conditions/type of land (i.e., wetlands, forest, etc.)

INDICATORS OF ENVIRONMENTAL IMPACT

Nationally, the *outcomes* of railroad infrastructure and construction activities on specific species and sensitive habitat are unknown. No data are available to estimate effects on species, habitat, or use of land area. Since construction and abandonment cases have been subject to environmental review, however, the impacts of such activities presumably have been considered and minimized. Moreover, new construction has been minimal over the past decade; impacts from new construction, therefore, are likely to be modest. Information is available only on the amount of infrastructure construction and abandonment taking place.

Since the mid-1980s, new rail lines primarily have been constructed for urban transit service. Miles of track owned by Class I railroads has been decreasing due to the sale of track to non-Class I railroads (including commuter railroads) and due to some abandonment.

[4] Surface Transportation Board, *1996/1997 Annual Report*

Table 4-1: Rail System Mileage in the U.S., 1960-1996

Year	Class I Rail[a]	Amtrak	Commuter Rail[b]	Heavy Rail[b]	Light Rail[b]
1960	207,334	N/A	N/A	N/A	N/A
1965	199,798	N/A	N/A	N/A	N/A
1970	196,479	N/A	N/A	N/A	N/A
1975	191,520	N/A	N/A	N/A	N/A
1980	164,822	24,000	N/A	N/A	N/A
1985	145,764	24,000	3,574	1,293	384
1990	119,758	24,000	4,132	1,351	483
1991	116,626	25,000	4,038	1,369	551
1992	113,056	25,000	4,013	1,403	558
1993	110,425	25,000	4,090	1,452	537
1994	109,332	25,000	4,090	1,455	562
1995	108,264	24,000	4,160	1,458	568
1996	105,779	25,000	6,364	1,477	638

Note: Portions of the Class-I freight, Amtrak, and Commuter Rail networks share common trackage.
[a] Data represent aggregate length of roadway, excluding yard tracks, sidings, and parallel lines. Jointly used track is only counted once.
[b] Transit system mileage is measured in directional route-miles. A directional route-mile is the mileage in each direction over which public transportation vehicles travel while in revenue service. Directional route miles are computed with regard to direction of service, but without regard to the number of traffic lanes or rail tracks existing in the right of way.

Source: U.S. Department of Transportation, Bureau of Transportation Statistics. *National Transportation Statistics 1998* (Table 1-1).

The Surface Transportation Board approved construction 288 miles of new track in FY 1996 and 1997. However, 230 of 288 approved miles were for lines on land already owned by the railroads.

Source: Surface Transportation Board. *1996/1997 Annual Report.*

549,726 tons of new rail were laid in 1997 by Class I railroads, the most in any year since 1985.

Source: “Did you Know”, in *Train It* (Official Newsletter of the Association of American Railroads), November 5, 1998, Vol. 5, No. 17.

In 1997, 264 miles of rail transit were under construction in the United States. This included 63 miles of light rail, 191 miles of commuter rail, 43 miles of heavy rail and 10 miles of automated guideway transit.

Source: American Public Transportation Asssociation (APTA). http://www.apta.com/stats/summary/summary.htm as cited on February 14, 1999.

Railway track and buffers occupy about 4 percent of the surface area in large cities.

Source: Tolley, R.S. and B.J. Turton. *Transport Systems, Policy and Planning: A Geographic Approach.* Longman Scientific and Technical. 1995.

EMISSIONS FROM CONSTRUCTION EQUIPMENT: CRITERIA AIR POLLUTANTS AND GREENHOUSE GASES

DESCRIPTION OF IMPACT

Machinery and haulage vehicles used in railroad infrastructure construction release criteria air pollutants, such as CO, VOC, NO_2, SO_2, PM-10, and Pb, as well as greenhouse gases.

FACTORS THAT AFFECT IMPACT

- Number of construction machinery and haulage vehicles
- Fuel consumed by construction equipment
- Fuel efficiency of construction machinery and haulage vehicles
- Frequency of use of construction machinery and haulage vehicles
- Duration of construction process

INDICATORS OF ENVIRONMENTAL IMPACT

National statistics for emissions from construction-related processes and equipment are not collected due to their temporary and project-specific nature. They are unlikely to be large in national terms given the limited amount of railroad construction.

HAZARDOUS WASTE AND TOXICS

DESCRIPTION OF IMPACT

Hazardous waste at or within railyards can be a problem associated with both railbed construction and rail car maintenance.

Creosote is a hazardous material applied to wood rail ties to protect against decay and rot. Over long time periods, leaching of creosote can become a problem for water quality and habitat. Creosote is a distillate of coal tar; it contains over 160 compounds but is composed primarily of liquid and solid aromatic hydrocarbons as well as some tar acids and tar bases which provide protection against destructive insects and organisms. Creosote contains impurities that are carcinogenic and mutagenic.

Coal tar creosote may dissolve in water and may move through the soil to the groundwater. Once it is in the groundwater, it may take many years for it to break down. Coal tar creosote can build up in plants and animals. The International Agency for Research on Cancer (IARC) and the EPA have determined that coal tar creosote is probably carcinogenic to humans.[5]

[5] ToxFAQs information (http://atsdr1.atsdr.cdc.gov:8080/tfacts85.html) derived from the "1996 Toxicological Profile for Creosote" produced by the Agency for Toxic Substances and Disease Registry, Public Health Service, U.S. Department of Health and Human Services, Public Health Service in Atlanta, GA.

FACTORS THAT AFFECT IMPACT

- Miles of track constructed/tons of new rail laid
- Type of construction (elevated, at-grade, underground)
- Ecological conditions/type of land (i.e., wetlands, forest, etc.)

INDICATORS OF ENVIRONMENTAL IMPACT

Information on the *outcomes* of hazardous materials associated with rail infrastructure construction is not available. It is known, however, that Class I Railroads laid 491,488 tons of rail and 14.27 million crossties in 1996, as shown in the table below:

Table 4-2: New Rail and Crossties Laid by Class I Railroads, 1955-1996

Year	New Rail Laid (tons)	Crossties Laid (thousands)
1955	963,350	27,173
1960	382,277	16,417
1965	445,863	16,982
1970	548,505	19,611
1975	537,537	20,548
1980	881,783	25,984
1985	699,774	20,736
1990	338,867	14,309
1991	299,385	12,844
1992	456,674	13,690
1993	441,381	13,233
1994	434,349	12,896
1995	443,084	12,784
1996	491,488	14,269

Source: Association of American Railroads. *Railroad Facts: 1997 Edition.* September 1997, p. 46

4.2 RAIL CAR AND PARTS MANUFACTURE

There are approximately 206 railroad equipment manufacturing facilities in the United States. Classified as SIC code 3743, these facilities produce locomotives and parts (both new and rebuilt), freight train and passenger train cars, transit rail cars, and railroad equipment. The industry is geographically concentrated in a few states, with 41 percent of all establishments located in three states: Illinois (38), Pennsylvania (28), and Texas (19).

The manufacture of railroad vehicles and engines involves use of a variety of materials and chemicals. Environmental impacts occur through the release of toxics and other wastes to the air, soil, and water.

CRITERIA AIR POLLUTANTS

DESCRIPTION OF IMPACT

Railroad equipment manufacturing generates emissions of air pollutants through various industrial processes.

FACTORS THAT AFFECT IMPACT

- Number of vehicles or parts built
- Amount of chemicals used in manufacture per vehicle or part
- Efficiency of processes and pollution prevention efforts

INDICATORS OF ENVIRONMENTAL IMPACT

Estimates from National Inventories

EPA's national emissions inventory estimates that vehicle manufacturing facilities (SIC code 3742) emitted the following quantities of pollutants:

Table 4-3: Criteria Pollutant Emissions from Vehicle Manufacturing Facilities, 1990-1996 (short tons)

Year	VOC	NO_x	CO	SO_2	PM-10
1990	3,587	8,094	993	9,329	3,402
1991	4,575	8,320	1,023	9,311	1,928
1992	4,600	8,321	1,024	9,322	1,930
1993	4,681	8,324	1,025	9,333	268
1994	4,794	8,286	1,034	9,304	263
1995	4,813	8,447	1,063	9,319	260
1996	4,764	8,447	1,063	9,319	260

Note: Based on SIC code 3743 for railroad equipment.

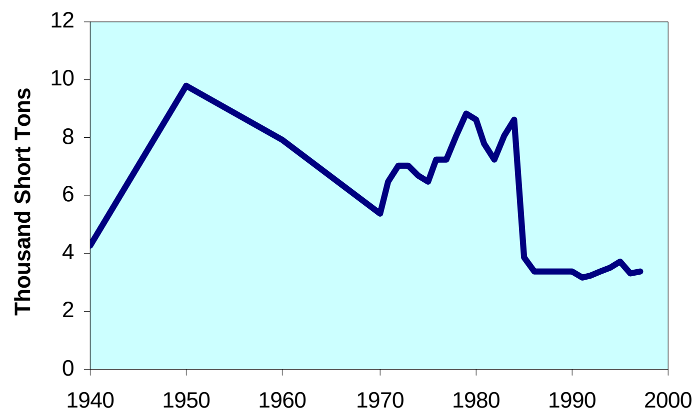
Source: U.S. Environmental Protection Agency. *NET Viewer*.

Most of the VOC emissions from rail manufacturing facilities come from solvent utilization in surface coating. Estimates of VOC emissions from solvent use in surface coating in rail equipment manufacture are presented in the table below. The estimates below do not correspond directly to those reported above because these include both point and air sources while the estimates above include only point sources.

Table 4-4: VOC Emissions from Solvent Utilization in Surface Coating for Rail Equipment (Point and Area Sources), 1940-1997

Year	Thousand Short Tons
1940	4
1950	10
1960	8
1970	5
1980	9
1985	4
1986	3
1987	3
1988	3
1989	3
1990	3
1991	3
1992	3
1993	3
1994	4
1995	4
1996	3
1997	3

Figure 4-1: VOC Emissions from Solvent Utilization in Surface Coating for Rail Equipment



Source: U.S. Environmental Protection Agency. *National Air Pollutant Emissions Trends Report, 1900-1997* (Table A-3).

Reports from Large Manufacturing Facilities

Reports of criteria pollutant emissions from individual large manufacturing facilities are compiled in EPA's AIRS database. These data are not complete because they do not include information from all manufacturing facilities or allow consistent tracking of trends. They do, however, provide a basis for comparing the contribution of rail equipment manufacturing facilities to the contribution of other point sources. AIRS suggests that the rail equipment industry contributes a very small percentage of total emissions from point sources.

Table 4-5: Pollutant Emissions from Rail Equipment Manufacturing Facilities reported to AIRS

Pollutant	Number of Facilities Reporting	Percent of Total Facilities Reporting	Pollutant Emissions (tons/year)	Percent of Total Emissions
Volatile Organic Compounds (VOC)	9	0.23%	2,898	0.16%
Carbon Monoxide (CO)	0	-	0	-
Nitrogen Dioxide (NO_2)	2	0.04%	3637	0.04%
Sulfur Dioxide (SO_2)	2	0.08%	7084	0.04%
Particulate Matter (PM_{10})	1	0.09%	119	0.03%

Source: U.S. Environmental Protection Agency, Office of Air and Radiation. *AIRS Database*. January 1999.

WASTES: TOXICS, WASTEWATER, AND SOILID WASTE

DESCRIPTION OF IMPACT

Railroad equipment manufacturing results in releases of chemicals to air, water, and land. Toxic chemicals are released on-site as emissions to the air, discharges to water, releases to land, and contained disposal or injection underground. Chemicals in waste may also be transferred off-site for disposal, in which case they are typically released to land at an off-site facility or injected underground.

Chemicals also may be transferred off-site for further waste management, including recycling, energy recovery, or treatment. Chemicals in wastewater are often transferred through pipes or sewers to publicly owned treatment works (POTWs). Treatment or removal of a chemical from the water depends upon the nature of the chemical and treatment methods used. Some chemicals are destroyed in treatment, while others evaporate into the atmosphere. Some are removed but are not destroyed by treatment and may be disposed of in landfills.

FACTORS THAT AFFECT IMPACT

- Number of vehicles or parts built
- Amount of chemicals used in manufacture per vehicle or part
- Efficiency of processes and pollution prevention efforts
- Amount of chemicals transferred to other locations for recycling, energy recovery, or treatment
- Types of chemicals released - toxicity
- Population density - extent of exposure

INDICATORS OF ENVIRONMENTAL IMPACT

Toxic Releases

No quantified data on human health impacts, such as increased incidence of cancer from toxics, or habitat and species impacts are available. According to the 1996 Toxic Release Inventory, 33 railroad equipment manufacturing facilities (SIC Code 3743) reporting to TRI released 1.5 million pounds of pollutants to the environment in 1996. Of these releases, 1.3 million pounds were released on-site and 0.2 million pounds were transferred off-site for disposal.

Source: U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics. *1996 Toxics Release Inventory Public Data Release – 10 Years of Right-to-Know: Industry Sector Analyses.* December 1998 (Table 14-1).

Of the total production-related toxic waste, 3 percent underwent on-site waste-management (recycling, use for energy recovery, or treatment on-site) and 56 percent was transferred off-site for waste-management.

Source: U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics. *1996 Toxics Release Inventory Public Data Release – 10 Years of Right-to-Know: Industry Sector Analyses.* December 1998 (Table 14-9).

Because chemicals have been added to the Toxic Release Inventory (TRI), deleted, or redefined over time, year-by-year tracking of releases must use a consistent set of chemicals. The following table reports only releases of "core" chemicals required to be reported in all years, 1988-1996.[6] Releases of core chemicals dropped 64 percent between 1988 and 1996.

Table 4-6: Toxic Chemicals (Core) Released from Railroad Equipment Manufacturing Facilities (SIC 3743), 1988-1996 (thousands of pounds per year)

Year	On-site Releases					Off-site	Total
	Air	Water	Under-ground injection	Direct to land	Total On-site Releases	Releases	Releases to the Environment
1988	**2,016.2**	**0.8**	**1.0**	**-**	**2,018.0**	**192.0**	**2,210**
1994	**1,496.6**	**0.0**	**-**	**-**	**1,496.6**	**409.0**	**1,906**
1995	**1,389.5**	**0.8**	**-**	**-**	**1,390.2**	**170.9**	**1,561**
1996	**1,252.6**	**0.0**	**-**	**0.0**	**1,252.6**	**172.3**	**1,425**

U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics. *1996 Toxics Release Inventory Public Data Release – 10 Years of Right-to-Know: Industry Sector Analyses.* December 1998 (Table 14-14).

[6] Tables for 1988 to 1996 include only chemicals that were reportable in all years for 1988 to 1996. These tables do not include, for example, chemicals added in 1990, 1991, 1994, or 1995. Because non-fibrous forms of aluminum were removed from the list in 1989, aluminum oxide is not included. Reporting definitions for ammonia, hydrochloric acid and sulfuric acid have also changed, and are not included in multi-year comparisons. The set of "core" chemicals differs depending on which years are being examined, so the figures in this table may not equal those in other tables that use different years.

4.3 RAIL TRAVEL

Freight rail transportation has experienced a boom in recent years, with uninterrupted growth in freight traffic since 1986. In 1996, the U.S. freight railroad industry carried a record level of traffic, and between 1994 and 1996 — despite a 3 percent drop in the miles of track owned — freight rail operators moved 13 percent more revenue ton-miles. Rail carried approximately 36 percent of total ton-miles of freight transportation in the U.S. in 1996.[7]

Passenger rail transportation, on the other hand — including Amtrak and the primary forms of transit (heavy rail/subways, light rail, and commuter rail) — carried a small portion of total personal travel. Rail carried less than 1 percent of total passenger miles traveled in the U.S. The percent of travel on rail is low for both short trips and long distance trips. Passenger travel on transit rail has been increasing in absolute numbers, however, as urban rail systems have expanded. Travel on light rail more than doubled from 381 million passenger miles in 1980 to about 950 million passenger miles in 1996 and travel on commuter rail increased from 6.5 billion to 8.4 billion passenger miles. Meanwhile, travel on heavy rail increased more moderately over the period 1980 to 1996 — from 10.6 billion passenger miles in 1980 to 11.5 billion passenger miles in 1996. Travel on intercity rail has fallen significantly since the 1960s, from 17.1 billion passenger miles in 1960 to a low of about 3.9 billion passenger miles in 1975; since then, ridership has risen and then fallen again to about 5.1 billion passenger miles in 1996.[8]

Rail transport directly affects the environment through emissions of air pollutants and greenhouse gases. Adverse impacts also include noise and hazardous materials incidents. These impacts are discussed below.

CRITERIA AIR POLLUTANTS

DESCRIPTION OF IMPACTS

Emissions from rail are associated with fuel combustion, primarily in diesel engines. Freight and passenger intercity rail generally burn diesel fuel; some passenger rail transport uses electric power sources.

While electric transit rail vehicles are "clean" and do not emit air pollutants, there are upstream emissions associated with electric generating facilities, so emissions from utilities should be considered when evaluating the environmental impacts of rail. The contribution of electric rail transport to atmospheric pollution depends of the type of power source used to generate electricity. While emissions from nuclear and hydro-electric power stations are minimal, coal and other fossil fuel power plants emit large quantities of NO_X, SO_X, and particulate matter, as well as smaller amounts of CO, VOC, and lead. Such power plants may be significant contributors to acid rain, for example.[9]

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[7] U.S. Department of Transportation, Bureau of Transportation Statistics. *National Transportation Statistics 1998* (Table 1-11).

[8] U.S. Department of Transportation, Bureau of Transportation Statistics. *National Transportation Statistics 1998* (Table 1-10).

[9] Water pollution from nuclear, coal, and other fossil fuel power plants consists primarily of thermal discharges from cooling water, which can cause adverse impacts to water chemistry, habitat, and species.

FACTORS THAT AFFECT IMPACT

- Amount of travel by type of engine
- Fuel efficiency
- Fuel consumed, by type
- Emissions rates
- Topographical conditions affecting pollutant dispersion (hills, valleys, etc.)
- Climatic conditions affecting pollutant dispersion and formation (temperature, wind, rain, etc.)
- Population density–exposure to pollution

INDICATORS OF ENVIRONMENTAL IMPACT

Air Pollutant Emissions

Rail emits a small portion of most air pollutants, with the exception of oxides of nitrogen. Rail emits approximately 4 percent of NO_X emissions in the U.S. In 1997, railroad operations resulted in the following emissions nationwide:

Table 4-7: Criteria Pollutant Emissions from Railroad Operations, 1997

Pollutant	Quantity Emitted (thousand short tons)	Percent of total Emissions of Pollutant
Carbon Monoxide (CO)	115	0.1%
Nitrogen Oxides (NO_x)	949	4.0%
Volatile Organic Comp. (VOCs)	50	0.3%
Sulfur Dioxide (SO_2)	114	0.6%
Particulate Matter (PM-10)	27	0.1%
Particulate Matter (PM-2.5)	25	0.3%
Lead (Pb)	NA	NA

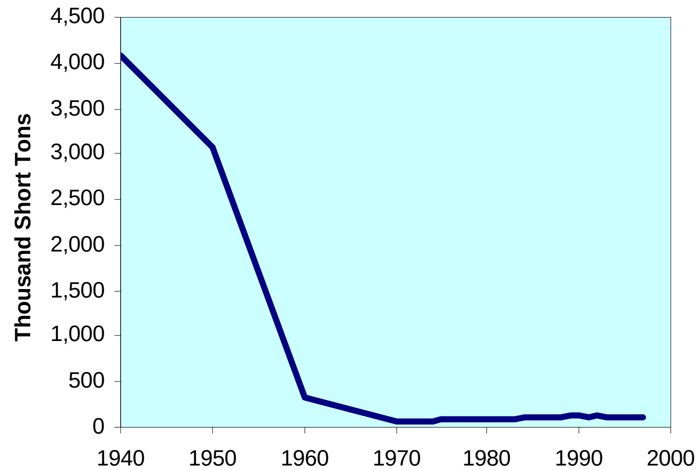
*Note: Percentage of emissions from traditionally inventoried sources (does not include agriculture and forestry, fugitive dust, or natural sources like windblown dust)
Source: U.S. Environmental Protection Agency. *National Air Pollutant Emission Trends, 1900-1997.*

Thermal discharges are regulated under the Clean Water Act. Hydro-electric power stations affect the flow and temperature of rivers by retaining water in reservoirs.

Table 4-8: CO Emissions from Railroad Operations, 1940-1997

Year	Thousand Short Tons
1940	4,083
1950	3,076
1960	332
1970	65
1980	96
1985	106
1986	109
1987	112
1988	118
1989	121
1990	121
1991	120
1992	125
1993	120
1994	114
1995	114
1996	112
1997	115

Figure 4-2: CO Emissions from Railroad Operations



Source: U.S. Environmental Protection Agency, *National Air Pollutant Emissions Trends, 1900-1997* (Table A-1).

Table 4-9: NO_x Emissions from Railroad Operations, 1940-1997

Year	Thousand Short Tons
1940	657
1950	992
1960	772
1970	495
1980	731
1985	808
1990	929
1991	929
1992	946
1993	945
1994	947
1995	990
1996	922
1997	949

Source: U.S. Environmental Protection Agency, *National Air Pollutant Emissions Trends, 1900-1997* (Table A-2).

Figure 4-3: NO_x Emissions from Railroad Operations

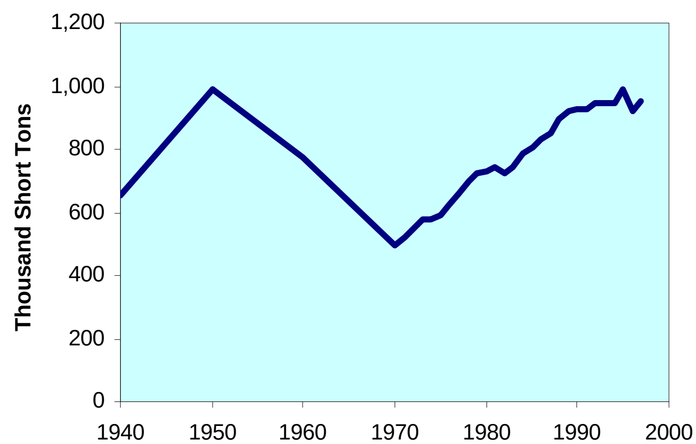


Table 4-10: VOC Emissions from Railroad Operations, 1940-1997

Year	Thousand Short Tons
1940	552
1950	551
1960	220
1970	22
1980	33
1985	37
1990	52
1991	52
1992	54
1993	52
1994	49
1995	49
1996	48
1997	50

Source: U.S. Environmental Protection Agency, *National Air Pollutant Emissions Trends, 1900-1997* (Table A-3).

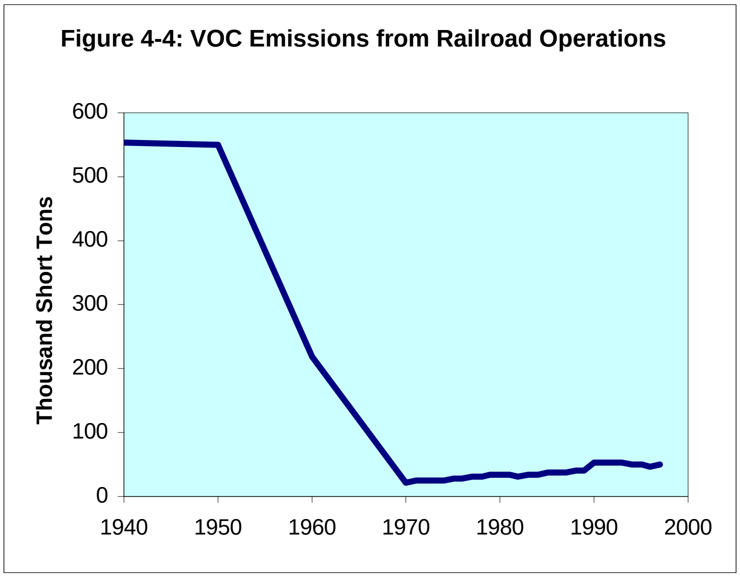


Table 4-11: SO_2 Emissions from Railroad Operations, 1940-1997

Year	Thousand Short Tons
1940	2,975
1950	2,174
1960	215
1970	36
1980	53
1985	59
1990	122
1991	120
1992	125
1993	117
1994	113
1995	113
1996	111
1997	114

Source: U.S. Environmental Protection Agency, *National Air Pollutant Emissions Trends, 1900-1997* (Table A-4).

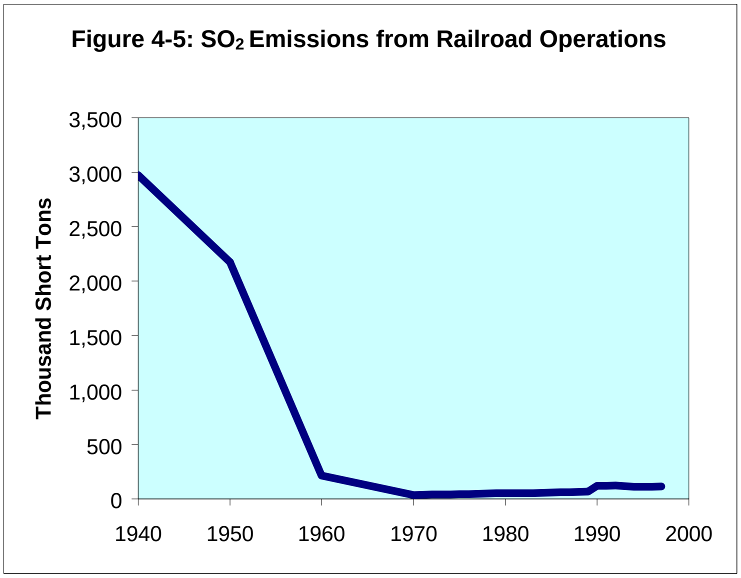


Table 4-12: PM_{10} Emissions from Railroad Operations, 1940-1997

Year	Thousand Short Tons
1940	2,464
1950	1,742
1960	110
1970	25
1980	37
1985	41
1990	53
1991	53
1992	54
1993	52
1994	50
1995	27
1996	27
1997	27

Source: U.S. Environmental Protection Agency, *National Air Pollutant Emissions Trends, 1900-1997* (Table A-5).

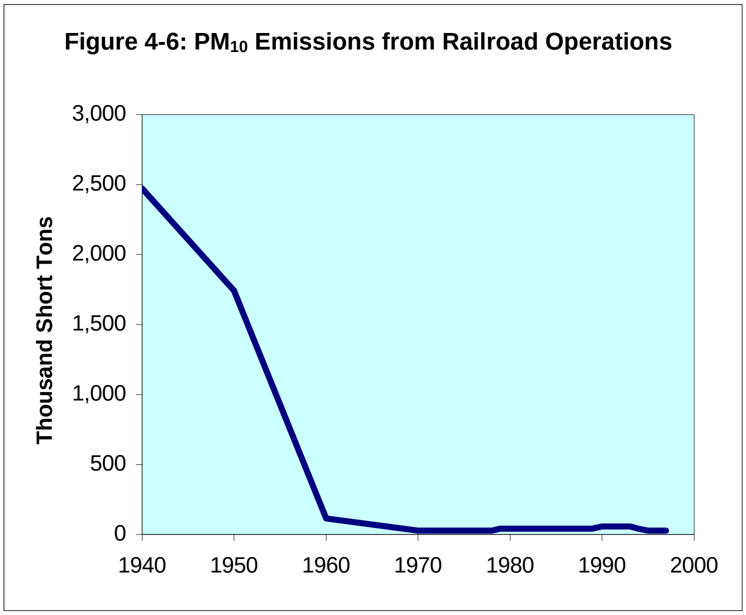
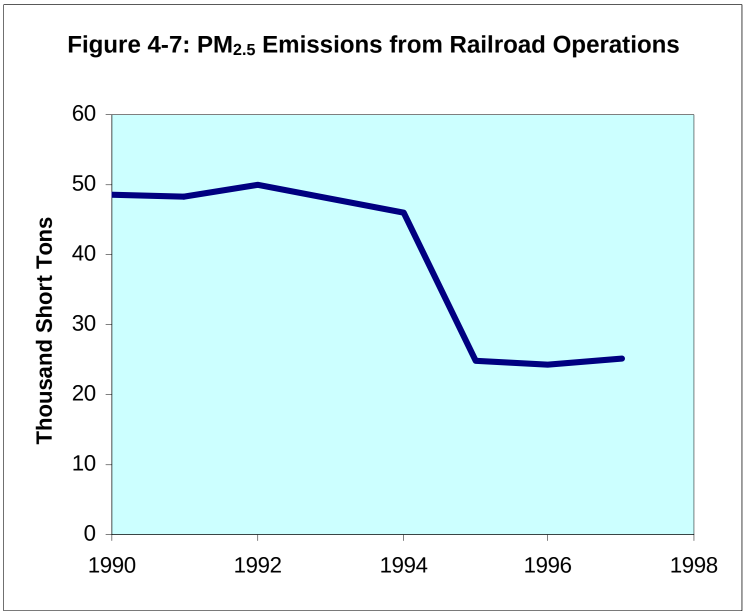


Table 4-13: $PM_{2.5}$ Emissions from Railroad Operations, 1990-1997

Year	Thousand Short Tons
1990	49
1991	48
1992	50
1993	48
1994	46
1995	25
1996	24
1997	25

Source: U.S. Environmental Protection Agency, *National Air Pollutant Emissions Trends, 1900-1997* (Table A-6).



GREENHOUSE GAS EMISSIONS

DESCRIPTION OF IMPACT

Fossil fuel consumption associated with rail travel is a source of greenhouse gas emissions.

FACTORS THAT AFFECT IMPACT

- Miles of travel
- Energy efficiency
- Type of fuel being used

INDICATORS OF ENVIRONMENTAL IMPACT

Carbon Dioxide Emissions

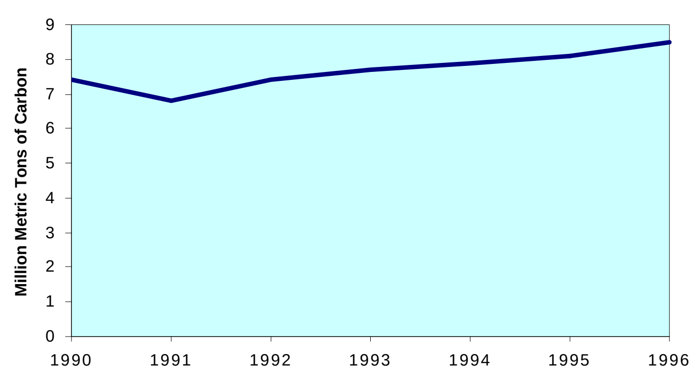
In 1996, CO_2 emissions from railroad operations accounted for approximately 8.5 million metric tons of carbon (MMTC). This equals about 1.9 percent of CO_2 emissions from transportation, or about 0.6 percent of CO_2 emissions from fossil fuel combustion nationwide.

Table 4-14: Carbon Dioxide Emissions from Fossil Fuel Combustion in Rail Travel (Million Metric Tons of Carbon)

Year	Distillate Fuel Oil (Diesel Fuel)	Electricity	Total Rail Emissions
1990	7.3	0.1	7.4
1991	6.7	0.1	6.8
1992	7.3	0.1	7.4
1993	6.6	1.1	7.7
1994	7.8	0.1	7.9
1995	8.0	0.1	8.1
1996	8.4	0.1	8.5

Source: U.S. Environmental Protection Agency, Office of Policy, Planning and Evaluation. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1996.* March 1998 (Table 2-6).

Figure 4-8: CO_2 Emissions from Railroads



Nitrous Oxide and Methane Emissions

Rail travel contributed a small amount of emissions of other greenhouse gases, as reported below for 1996:

Table 4-15: Nitrous Oxide and Methane Emissions from Rail Travel, 1996

Pollutant	Thousand metric tons of gas	Million metric tons of carbon equivalent
Methane (CH_4)	3	<0.05
Nitrous Oxide (N_2O)	1	0.1

Source: U.S. Environmental Protection Agency, Office of Policy, Planning and Evaluation. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1996.* March 1998 (Tables 2-12, 2-13, 2-14, 2-15).

NOISE

DESCRIPTION OF IMPACTS

Noise associated with rail transport comes from engine operations, rail-wheel contact, aerodynamic effects, and vibrating structures during operations. Although at the national level, railroad noise does not appear to be a significant problem, at the local level, noise impacts from rail may be severe depending on population density near rail lines and frequency of operations.

FACTORS THAT AFFECT IMPACT

- Level of rail activity (miles of travel, frequency of service) by rail type
- Speed
- Population near rail
- Distance between population/housing and rail operations
- Background noise level
- Natural noise barriers (topography, vegetation)
- Mitigation (designed noise barriers and control devices)

INDICATORS OF ENVIRONMENTAL IMPACT

Recent information on national population exposure is not readily available. It was estimated that one percent of the population of the U.S. was exposed to noise levels above Leq 65 dB(A) in 1980. Exposure to different levels of noise are shown below:

Table 4-16: Percent of U.S. Population Exposed to Rail Transportation Noise, 1980
Outdoor Sound Level in Leq [dB(A)] and Associated Effects

>55 dB(A) Annoyance	>60 dB(A) Normal Speech Level	>65 dB(A) Communication Interference	>70 dB(A) Muscle/Gland Reaction	>75 dB(A) Changed Motor Coordination
2.4%	1.4%	1.0%	0.2%	n/a

Source: Organization for Economic Cooperation and Development. *Indicators for the Integration of Environmental Concerns into Transport Policies.* OECD Publications, 1993.

Typical noise emissions are loud: 93 dB for a diesel locomotive and 89 dB for an electric locomotive, and 120 dB(A) for a locomotive whistle.

Source: U.S. Department of Transportation, Bureau of Transportation Statistics. *Transportation Statistics Annual Report 1996* as adapted from P.M. Nelson ed., *Transportation Noise Reference Book*, Butterworths, London, England, 1987 and Truls, Berge, "Vehicle-Noise Emissions Limits: Influence on Traffic Noise Levels Past and Future," *Noise Control Engineering Journal*, vol. 42, No. 2, March April 1994.

HAZARDOUS MATERIALS INCIDENTS DURING TRANSPORT

DESCRIPTION OF IMPACT

The potential for commodity spills during rail transportation is important to consider because of the large role rail plays in domestic freight movement. In 1996, rail transport moved 36% of the freight ton-miles in the United States.[10] In 1991 — the most recent year for which much competitive data are available — railroads transported 65.9 billion hazardous cargo ton-miles on movements greater than 200 miles.[11]

Commodity spills of hazardous materials may impose substantial costs for product loss, carrier damage, property damage, evacuations, and response personnel and equipment. The Hazardous Materials Information System (HMIS) database, maintained by U.S. DOT/Research and Special Projects Administration (RSPA), contains a record of all reported hazardous materials incidents occurring during rail transport, including type of material released, number of injuries/fatalities, and estimated cleanup costs.

The number of hazardous material incidents is not necessarily indicative of the environmental impact of such incidents since it may be possible to clean up most of the materials released. If not properly contained, however, hazardous materials incidents may cause long term environmental damage such as water pollution, damage to fish and wildlife, habitat destruction, and aesthetic or recreational losses. While the overall impact of rail spills may be small for the nation as a whole, any hazardous material spill may have severe impacts on flora and fauna in the location of occurrence.

FACTORS THAT AFFECT IMPACT

The environmental impact of any given hazardous materials spill is highly site-specific. It depends on the type and quantity of material spilled, amount recovered in cleanup, chemical properties (such as toxicity and combustibility), and impact area characteristics (such as climatic conditions, flora and fauna density, and local topography). Factors that affect environmental outcomes include:

- Quantity of hazardous materials transported and distance transported
- Accident or spill rate
- Type and quantity of materials spilled
- Cleanup efforts
- Population density

[10] U.S. Department of Transportation, Bureau of Transportation Statistics. *National Transportation Statistics 1998* (Table 1-11).
[11] Association of American Railroads. "Rail Facts and Statistics: North America's Freight Railroads On-line." http://www.aar.org/aarhome.nsf?OpenDatabase

- Sensitivity of local habitats/species

INDICATORS OF ENVIRONMENTAL IMPACT

No statistics were found regarding the number of species or acres nationwide affected by commodity spills; that is, on *outcomes* from hazardous materials spills during rail transport. Data is available to measure the number of incidents, however:

An average of 1,150 hazardous materials spills occurred annually during rail transport in the U.S. between 1990 -1997. Of the hazardous materials rail incidents reported to HMIS in 1997, 52% resulted from human error, 41% from packaging failure, 4.6% from vehicle accidents/ derailments, and 2.5% from other causes.

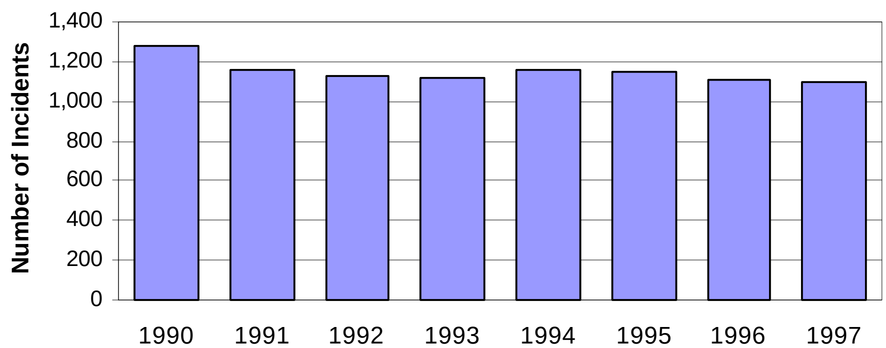
Source: U.S. Department of Transportation, Research & Special Programs Administration. *Hazardous Materials Information System*. http://hazmat.dot.gov/1997frm.htm

Table 4-17: Railroad Hazardous Materials Incident Totals, 1990-1997

Year	Number of Incidents[1]	Gallons Released	Pounds Released	Cubic Feet Released	MilliCuries Released[2]	Clean Up & Product Loss Damages
1990	1,279	554,306.75	807,723.31	240.69	0	$8,166,267
1991	1,155	428,777.16	841,694.38	99.26	0	$4,487,534
1992	1,129	253,423.59	517,595.25	6,413.67	0	$9,313,242
1993	1,120	475,352.16	219,131.50	4.07	0	$1,796,536
1994	1,157	304,866.72	416,616.94	8.3	0	$13,494,785
1995	1,153	307,577.41	294,139.69	4,450.82	0	$2,679,000
1996	1,108	833,694.44	220,480.31	251.9	0	$14,179,638
1997	1,096	268,049.91	95,636.02	332.87	0	$5,153,275

[1] Due to multiple classes being involved in a single incident, the totals above may not correspond to the totals in other reports.
[2] MilliCuries (mCi) are a measure of radioactivity.
Source: Data obtained from the Office of Hazardous Materials Safety, Research & Special Programs Administration (RSPA), U.S. DOT, Hazardous Materials Information System (HMIS)

Figure 4-9: Railroad Hazardous Materials Incidents, 1990-1997



In 1997, the four classes of materials most commonly involved in rail incidents were: corrosive materials, flammable-combustible liquids, nonflammable compressed gases, and miscellaneous hazardous materials.

Table 4-18: Railroad Hazardous Materials Incidents, 1997

Hazard Class	Number of Incidents[1]	Gallons Released*	Pounds Released*	Cubic Feet Released*	MiliCuries Released*[2]	Clean Up & Product Loss Damages
Corrosive Material	398	98,389.6	20.5	0	0	$1,758,580
Flammable - Combustible Liquid	343	82,649.2	0	0	0	$1,894,749
Nonflammable Compressed Gas	113	19,171.0	0	330.6	0	$706,420
Miscellaneous Hazardous Material	78	4,118.4	50,124.0	0	0	$85,610
Flammable Gas	64	32,109.3	0	2.3	0	$32,419
Combustible Liquid	46	11,134.2	0	0	0	$69,670
Poisonous Materials	27	121.6	4	0	0	$33,752
Oxidizer	23	20,318.0	45,412.5	0	0	$477,075
Poisonous Gas	10	0.1	0	0	0	$0
Radioactive Material	6	0	0	0	0	$90,000
Flammable Solid	4	0	74	0	0	$5,000
Dangerous When Wet Material	3	38.5	1	0	0	$0
Explosive Mass Explosion Hazard	1	0	0	0	0	$0
Other Category	0	0	0	0	0	$0
TOTALS	1,096	268,049.9	95,636.0	332.9	0	$5,153,275

1 The total for incident number is not equal to the sum of incidents by hazard class, because one incident may be reported under two or more hazard classes. The total for incidents does not double count incidents reported under multiple classes.
2 MilliCuries (mCi) are a measure of radioactivity.
*Quantities shown are the total of all reported releases. For some incidents, the quantity released is unknown and, therefore, not included in the hazard class or mode totals.
Source: Data obtained from the Office of Hazardous Materials Safety, U.S. DOT, Research & Special Programs Administration (RSPA), Hazardous Materials Information System (HMIS)

4.4 RAIL OPERATIONS, MAINTENANCE AND SUPPORT

Besides trains and track, rail transport requires support facilities such as terminals and fueling stations. In 1996, there were 542 passenger rail stations served by Amtrak, and 2,587 transit stations (heavy, light, and commuter rail) in the U.S.[12]

RELEASES DURING TERMINAL OPERATIONS: EMISSIONS, WASTEWATER, SOLID WASTE

DESCRIPTION OF IMPACT

Terminal operations include line haul railroad activities (such as tank car unloading and cleaning, equipment degreasing, exterior washing, and painting), furnishing of terminal facilities for passenger or freight traffic, and the movement of railroad cars between terminal yards. Many of these processes use materials that are hazardous or may in turn generate hazardous waste or wastewater. In addition, refueling operations affect the environment through spills and drips of fuel, and through fuel tank vapors that are displaced when the tank is filled with liquid fuel. The following table summarizes some of the main wastes generated in rail terminal operations.

Table 4-19: Typical Railroad Terminal Operations: Materials Used and Types of Waste Possibly Generated

Process/ Operation	Materials Used	Types of Waste Generated
Unloading or Cleaning of Tank Cars	Solvents, alkaline cleaners	Acid/alkaline wastes Toxic wastes Solvent wastes Residual tank contents
Rust Removal	Naval jelly, strong acids, strong alkalies	Acid/alkaline wastes
Painting	Enamels, lacquers, epoxies, alkyds, acrylics, primers, solvents	Ignitable wastes Toxic wastes Paint wastes Solvent wastes
Paint Removal	Solvents, paint thinners, enamel, white spirits	Paint wastes Toxic wastes Solvent wastes
Exterior Washing	Solvents, cleaning solutions	Solvent wastes Oil and grease
Equipment degreasing	Degreasers, engine cleaners, acids, alkalies, cleaning fluids	Ignitable waste Combustible solids Acid/alkaline wastes
Refueling	Diesel fuel	Evaporative losses Fuel drips and spills

Sources: U.S. EPA/RCRA Fact Sheet: Motor Freight/Railroad Terminal Operations, 1993; U.S. Environmental Protection Agency. *EPA Office of Compliance Sector Notebook Project: Profile of the Transportation Equipment Cleaning Industry.* September 1995.

[12] U.S. Department of Transportation, Bureau of Transportation Statistics. *National Transportation Statistics 1998* (Table 1-6).

The cleaning of rail tank interiors is a major source of pollution during terminal operations. The typical rail tank car has a volume of 20,000 - 30,000 gallons. Wastewater during cleaning results in the output of spent cleaning fluids, fugitive VOC emissions, water treatment system sludges, and tank residues. The disposal and treatment of tank heels (the material left in the tank after unloading) can also be a source of pollution for tank cleaning facilities. A facility's wastewater treatment system may be adversely affected by, or may not adequately treat, a slug of concentrated tank residue. Incompatible heels are usually segregated and resold to a reclaimer or shipped off-site for disposal. Heels that are composed of detergents, solvents, acids, of alkalis can be stored on-site and used as tank cleaning fluids or to neutralize other tank heels.

The washing and maintenance of rail car exteriors generates relatively small amounts of waste and wastewater. Typical hazardous wastes generated include spent solvents, spent caustics, paint chips, and paint sludges. Wastewater is generally treated on-site and then discharged to a public treatment works.

Other potential environmental impacts of terminal operations include air emissions and residual wastes. Fugitive emissions of VOCs arise from tank heels and residues, cleaning solutions, painting, paint stripping, and refueling vapors. Residual wastes are generated as sludges from wastewater treatment systems, residues removed from the inside of tanks, hazardous wastes from painting, paint removal, and cleaning of parts.[13]

Environmental impacts associated with maintenance activities include wastewater runoff from cleaning; volatile organic compound discharges (VOCs) from solvent and paint use; and hazardous materials discharges from painting, paint removal, and the cleaning of parts. The repair and cleaning of locomotives, moreover, may entail a variety of environmental impacts, such as those associated with the disposal of asbestos brake shoes and waste oil seepage.

FACTORS THAT AFFECT IMPACT

The actual impact of terminal activities on the environment depends in a large part on the type and volume of operations, level of cleanliness required, type of waste generated, and efficacy of wastewater treatment systems in place. Factors that affect environmental impacts include:

- ♦ Number of terminals
- ♦ Type and level of terminal operations
- ♦ Materials used during terminal operations
- ♦ Wastewater treatment capabilities

INDICATORS OF ENVIRONMENTAL IMPACT

Air Pollution from Railway Maintenance

National emissions inventories compiled by EPA present estimates of criteria pollutant emissions associated with railway maintenance. As shown in the charts below, railway maintenance is responsible for a very small portion of emissions nationwide:

[13] Source: U.S. Environmental Protection Agency. *EPA Office of Compliance Sector Notebook Project: Profile of the Transportation Equipment Cleaning Industry.* September 1995.

Table 4-20: Criteria Pollutant Emissions from Railway Maintenance, 1997

Pollutant	Quantity Emitted (thousand short tons)	Percent of total Emissions of Pollutant
Carbon Monoxide (CO)	3	0.0%
Nitrogen Oxides (NO_x)	NA	NA
Volatile Organic Comp. (VOCs)	1	0.0%
Sulfur Dioxide (SO_2)	NA	NA
Particulate Matter (PM-10)	1	0.0%
Particulate Matter (PM-2.5)	NA	NA
Lead (Pb)	NA	NA

*Note: Percentage of emissions from traditionally inventoried sources (does not include agriculture and forestry, fugitive dust, or natural sources like windblown dust)
Source: U.S. Environmental Protection Agency. *National Air Pollutant Emission Trends, 1900-1997.*

Table 4-21: CO Emissions from Railway Maintenance, 1986-1997

Year	Thousand Short Tons
1986	1.64
1987	1.71
1988	1.85
1989	1.99
1990	2.14
1991	2.30
1992	2.46
1993	2.63
1994	2.81
1995	3.00
1996	3.15
1997	3.00

Source: U.S. Environmental Protection Agency, *National Air Pollutant Emissions Trends, 1900-1997* (Table A-1).

Figure 4-10: CO Emissions from Railway Maintenance

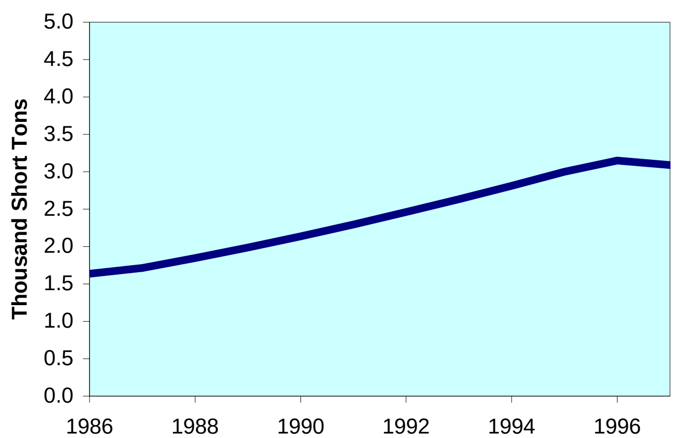


Table 4-22: VOC Emissions from Railway Maintenance, 1987-1997

Year	Thousand Short Tons
1987	0.74
1988	0.76
1989	0.77
1990	0.79
1991	0.81
1992	0.83
1993	0.86
1994	0.88
1995	0.90
1996	0.92
1997	0.91

Source: U.S. Environmental Protection Agency, *National Air Pollutant Emissions Trends, 1900-1997* (Table A-3).

Figure 4-11: VOC Emissions from Railway Maintenance

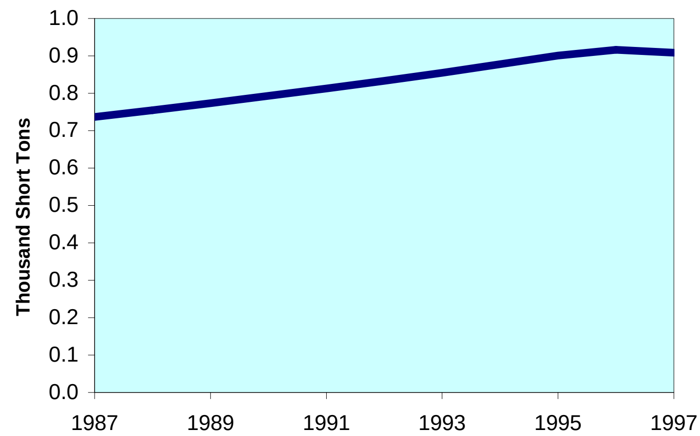
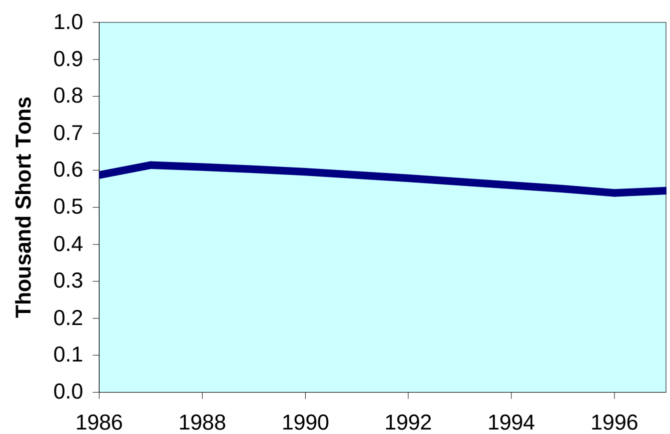


Table 4-23: PM_{10} Emissions from Railway Maintenance, 1986-1997

Year	Thousand Short Tons
1986	0.59
1987	0.61
1988	0.61
1989	0.60
1990	0.60
1991	0.59
1992	0.58
1993	0.57
1994	0.56
1995	0.55
1996	0.54
1997	0.54

Source: U.S. Environmental Protection Agency, *National Air Pollutant Emissions Trends, 1900-1997* (Table A-5).

Figure 4-12: PM_{10} Emissions from Railway Maintenance



Air Pollution Reports from Large Point Sources

Reports of criteria pollutant emissions from large point sources, such as line-haul operating railroad facilities, are compiled in EPA's AIRS database. These data are not complete because they do not include information from all facilities or allow consistent tracking of trends. They do, however, provide a basis for comparing the contribution of railroads to other large point sources. Line-Haul Operating Railroads contribute a very small portion of national emissions of air pollutants.

Table 4-24: Pollutant Emissions from Line-Haul Operating Railroads (SIC 4011) reported to AIRS

Pollutant	Number of Facilities Reporting	Percent of Total Facilities Reporting	Pollutant Emissions (tons/year)	Percent of Total Emissions
Volatile Organic Compounds (VOC)	2	0.05%	263	0.01%
Carbon Monoxide (CO)	0	-	0	-
Nitrogen Dioxide (NO_2)	2	0.04%	382	0
Sulfur Dioxide (SO_2)	2	0.08%	1,639	0.01%
Particulate Matter (PM_{10})	0	-	0	-

Source: U.S. Environmental Protection Agency, Office of Air and Radiation. *AIRS Database*. January 1999.

Waste Water

Data on water quality impacts to streams, rivers, and lakes, and related habitat due to rail terminal operations are not available. Data on health effects from air pollution coming from terminals are also not available.

Estimated typical heel volume from rail tank cars is 10 to 30 gallons per tank, and average wastewater generated from rail tank cars is 3,000 to 5,000 gallons per tank. Some facilities discharge directly to surface waters under NPDES permits or to underground injection wells under Safe Drinking Water Act permits.

Source: U.S. Environmental Protection Agency. *EPA Office of Compliance Sector Notebook Project: Profile of the Transportation Equipment Cleaning Industry.* September 1995, p. 21.

4.5 DISPOSAL OF RAIL CARS AND PARTS

SOLID WASTE

DESCRIPTION OF IMPACTS

Rail cars and their parts are scrapped, refurbished or recycled as they wear out. In addition, many rail cars and their components are exported. Disposal practices may allow the release of toxic substances into water, air, or soil.

FACTORS THAT AFFECT IMPACT

- Quantity of metals and oil used in rail operations.
- Recovery rate
- Groundwater contamination and seepage prevention measures at the disposal site.

INDICATORS OF ENVIRONMENTAL IMPACT

Estimates are not available on the health and environmental impacts of landfilling or other disposal of scrapped rail cars and parts. Rail equipment makes up a very small portion of the solid waste steam, and so impacts are expected to be small nationally.

5. AVIATION ENVIRONMENTAL INDICATORS

This chapter describes the environmental impacts of air transportation and presents quantitative indicators available for tracking the nationwide environmental impacts of aviation. Aviation is defined here to encompass all domestic air travel, including major air carriers and general aviation, freight and passenger travel. Impacts are described for five categories of aviation activities:

- Airport Construction and Infrastructure Improvement
- Aircraft and Parts Manufacture
- Air Travel
- Aviation Operations and Support
- Disposal of Aircraft and Parts

5.1 AIRPORT CONSTRUCTION AND INFRASTRUCTURE IMPROVEMENT

Airport construction, expansion, and configuration changes can cause a number of adverse environmental impacts. Airport construction activities may have temporary environmental impacts, such as air pollutant emissions and noise from construction equipment, as well as site-specific erosion and solid waste impacts. Infrastructure development may also have long term environmental consequences, including habitat disruption and hydrologic alterations.

Airport infrastructure activities include development of new airports or alterations to existing facilities, such as the addition or reconfiguration of runways, terminals, parking facilities, or other support facilities. Only one major scheduled passenger service airport — Denver International Airport — has been constructed since 1974. However, there were 5,357 public use airports and 12,988 private use airports in the United States in 1997, and a variety of infrastructure projects are ongoing within the national airport system.[1] Projects are undertaken for a variety of reasons including capacity enhancement, safety improvements, rehabilitation, or improvements to meet current airport design and operational standards. Environmental requirements affect the degree to which airport infrastructure changes can adversely affect the natural environment, and environmental assessments must be undertaken for all major infrastructure projects.

HABITAT AND LAND USE

DESCRIPTION OF IMPACT

Airport construction and expansion activities have potential short-term and long-term impacts on habitat and land use. Environmental impacts during airport construction and expansion are associated with land clearing, blasting, ground excavation, earth moving; cement, asphalt, and aggregate handling; heavy equipment operation; use of haul roads; and erosion of exposed areas

[1] U.S. Department of Transportation, Bureau of Transportation Statistics. *National Transportation Statistics 1998.* Table 1-2.

and material storage piles. Temporary storage facilities for equipment and supplies used during the construction phase may also damage vegetation and displace communities of animals.

Long term impacts associated with new or expanded airport infrastructure include elimination of and damage to vegetation, interference with wildlife, displacement of forests and communities of animals and birds, and alteration of hydrology. Airport and runway construction can result in wetland losses, although mitigation of these losses is required. Impacts on wildlife and habitat depend on the extent and types of habitat that are disturbed and the availability of comparable habitats near the site.

FACTORS THAT AFFECT IMPACT

The environmental impact of a particular project depends on the condition of the surrounding area, the size of the airport, and the length of project duration. Nationally, impacts tend to depend upon the following factors:

- Number of new airports constructed
- Number of runway and other airport capacity enhancements
- Ecological conditions/type of land (i.e., wetlands, forest, etc.)
- Successful airport implementation of various efforts to avoid or mitigate impacts (i.e., stormwater treatment)

INDICATORS OF ENVIRONMENTAL IMPACT

Nationally, the outcomes of airport infrastructure and construction activities on species and sensitive habitat are unknown. No quantified data are available to estimate effects on species, habitat, or use of land area.

The number of airports in the U.S. increased by 21 percent between 1980 and 1997; most of this increase was in private-use, general aviation airports.

Table 5-1: Number of Airports in the U.S., 1980-1997

Year	Public-Use Airports	Private-Use Airports	Certificated[a]	General Aviation	Total Airports
1980	4,814	10,347	730	14,431	15,161
1985	5,858	10,461	700	15,619	16,319
1990	5,589	11,901	680	16,810	17,490
1991	5,551	12,030	669	16,912	17,581
1992	5,545	12,301	664	17,182	17,846
1993	5,538	12,779	670	17,647	18,317
1994	5,474	12,869	672	17,671	18,343
1995	5,415	12,809	667	17,557	18,224
1996	5,389	12,903	671	17,621	18,292
1997	5,357	12,988	660	17,685	18,345

[a] Certificated airports serve air carrier operations with aircraft seating more than 30 passengers.

Source: U.S. Department of Transportation, Bureau of Transportation Statistics. *National Transportation Statistics 1998* (Table 1-2).

EMISSIONS FROM CONSTRUCTION EQUIPMENT

DESCRIPTION OF IMPACT

Criteria air pollutants, such as CO, VOC, NO_2, SO_2, PM-10, and Pb, are released as exhaust and evaporative emissions from machinery and haulage vehicles. Dust emissions, a large portion of which result from construction equipment traveling over temporary roads at construction sites, may have substantial temporary impacts on local air and water quality.

FACTORS THAT AFFECT IMPACT

- Number of new airports constructed
- Number of construction machinery and haulage vehicles
- Fuel efficiency of construction machinery and haulage vehicles
- Frequency of use of construction machinery and haulage vehicles
- Duration of construction process

INDICATORS OF ENVIRONMENTAL IMPACT

No data are available nationally on the level of emissions of criteria pollutants from construction equipment associated with airport infrastructure improvements.

HAZARDOUS WASTE

DESCRIPTION OF IMPACT

Hazardous waste on airport property (especially older Army and Air Force bases) sometimes can be a problem during airport construction and expansion. Often, airport construction and infrastructure improvements are a source of hazardous waste problems due to the use of hazardous materials, such as lead paint, solvents, and pesticides.

FACTORS THAT AFFECT IMPACT

- Number of new airports constructed
- Number of runway and other airport capacity enhancements
- Ecological conditions/type of land (i.e., wetlands, forest, etc.)
- Implementation of various efforts to avoid or mitigate impacts

INDICATORS OF ENVIRONMENTAL IMPACT

No national-level data are available on hazardous waste problems associated with airport infrastructure improvements.

RUNOFF AND WATER QUALITY IMPACTS

DESCRIPTION OF IMPACT

Water quality in wetlands and streams may be affected by construction and post-construction activities. Stormwater run-off from runways/taxiways, aprons, roads and parking lots, for example, will result in an increase in pollutant loading to wetlands and streams unless stormwater treatment facilities are included as part of airport construction. An increase in the amount of impervious surfaces and the elimination of recharge areas, such as wetlands, affect the low flow characteristics of streams by reducing groundwater recharge capabilities. This may result in a reduction of the carrying capacity of streams and elevated water temperatures, which, in turn, may increase stress levels in fish as well as reduce feeding and growth. Additionally, water flow from paved runways and other airport facilities can increase erosion of surrounding soil and add to silt problems in surrounding waterways. Erosion may also increase during construction when vegetation is cleared away and soil is exposed to wind and rain.

FACTORS THAT AFFECT IMPACT

- Number of airports and paved surface area
- Number of runway and other airport capacity enhancements
- Precipitation activity
- Drainage characteristics
- Ecology and other aspects of receiving water bodies: type, size, diversity, potential for dispersion
- Successful implementation of mitigation efforts (i.e., stormwater treatment)

INDICATORS OF ENVIRONMENTAL IMPACT

Nationally, the outcomes of airport construction and infrastructure on water quality are not available. It is known, however, that the percentage of airports with paved runways has increased since 1980.

Table 5-2: Percent of Airports with Paved Runways, 1980-1997

Year	Public-Use Airports, total	Percent with Paved Runways	Private-Use Airports, total	Percent with Paved Runways
1980	4,814	72.0	10,347	14.1
1985	5,858	66.7	10,461	17.4
1990	5,589	70.7	11,901	31.5
1991	5,551	71.5	12,030	32.0
1992	5,545	71.6	12,301	32.2
1993	5,538	72.2	12,779	32.7
1994	5,474	72.9	12,869	33.0
1995	5,415	73.3	12,809	33.0
1996	5,389	73.7	12,903	32.9
1997	5,357	74.0	12,988	33.0

Source: U.S. Department of Transportation, Bureau of Transportation Statistics. *National Transportation Statistics 1998* (Table 1-2).

5.2 AIRCRAFT AND PARTS MANUFACTURE

There are approximately 1,745 aircraft and parts manufacturing facilities in the United States. Of these, 182 are primarily involved with aircraft manufacture, 442 with aircraft engines and engine parts, and 1121 with other aircraft parts.[2] These facilities fall under the following SIC industry codes: 3720 (aircraft and parts - general), 3721 (aircraft), 3724 (aircraft engines and engine parts), and 3728 (aircraft parts and auxiliary equipment). The industry is geographically concentrated in a few states, with 45 percent of all manufacturing establishments located in four states: California (393), Texas (140), Washington (136), and Connecticut (126).

Manufacturing processes for aircraft engines and parts consist of materials receiving, metal fabricating, machining and mechanical processing, coating application, chemical milling, heat treating, cleaning, metal processing and finishing, coating removal (depainting), composite processing, and testing. Aircraft assembly requires the coordination of thousands of parts coming together to form one large final product. Thousands of different materials are used in airplane and parts manufacturing and refurbishing, including metals, solvents, paints and coatings, plastics, rubbers, and fabrics. This range of 15,000 to 30,000 materials contains many chemicals that are potentially toxic, highly volatile, flammable, or contribute to global warming.[3] Other materials may pose no environmental threat as originally introduced to the manufacturing process, but become contaminants when ground into a fine dust or combined with other materials and introduced into waste water or related fluids during manufacturing and refurbishing.

CRITERIA AIR POLLUTANTS

DESCRIPTION OF IMPACT

Aircraft and parts manufacture generates emissions of air pollutants through various industrial processes. Volatile organic compounds (VOCs), which can combine with ambient oxides of nitrogen (NO_X) to produce ozone, are released during airplane manufacturing and refurbishing operations such as chemical milling, metal finishing, coating, painting and depainting. Generally, solvents used in these applications are the source of VOCs released during manufacturing and refurbishing.

FACTORS THAT AFFECT IMPACT

- Number of airplanes manufactured
- Number of spare parts manufactured
- Number of airplanes refurbished
- Quantity of solvents used in cleaning, coating, painting, depainting, etc.

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[2] U.S. Department of Commerce, Bureau of the Census, Economics and Statistics Administration. *1992 Census of Manufactures Industry Series, Aerospace Equipment, Including Parts,* 1995. As cited in U.S. Environmental Protection Agency, Office of Compliance. *EPA Office of Compliance Sector Notebook Project: Profile of the Aerospace Industry*, Draft, August 1998, p. 8.
[3] Environmental Protection Agency, *EPA Office of Compliance Sector Notebook Project: Profile of the Aerospace Industry*, Draft, August 1998, p. 34.

INDICATORS OF ENVIRONMENTAL IMPACT

Estimates from National Inventories

Quantified information on criteria pollutant emissions from aircraft and parts manufacturing facilities can be extracted from EPA's national emissions inventory. These estimates include only point sources.

Table 5-3: Criteria Pollutant Emissions from Aircraft Manufacturing Facilities, 1990-1996 (short tons)

Year	VOC	NOx	CO	SO2	PM-10
1990	13,087	7,554	2,289	5,515	802
1991	16,081	5,784	2,310	5,392	895
1992	16,970	6,292	2,602	5,330	894
1993	16,183	6,197	2,911	5,225	920
1994	14,942	6,248	2,846	5,111	875
1995	14,324	6,031	2,812	5,095	854
1996	11,182	6,026	2,812	5,095	854

Note: Based on following SIC codes--3721, 3724, and 3728. Although considered in calculations of toxic releases, 3720 is not included here, because it is not covered by the NET database.

Source: U.S. Environmental Protection Agency. *NET Viewer*.

Pollutant emissions from aircraft manufacturing facilities by SIC code are presented below:

Table 5-4: Criteria Pollutant Emissions from Aircraft Manufacturing Facilities by SIC Code, 1996 (short tons)

SIC	Industry Type	VOC	NO_x	CO	SO_2	PM-10
3721	Aircraft	7,658	2,808	1,513	735	128
3724	Aircraft Engines & Engine Parts	1,496	2,810	1,131	4,203	666
3728	Aircraft Part & Auxiliary Equipment, NEC	2,028	408	168	158	59
-	TOTAL	11,182	6,026	2,812	5,095	854

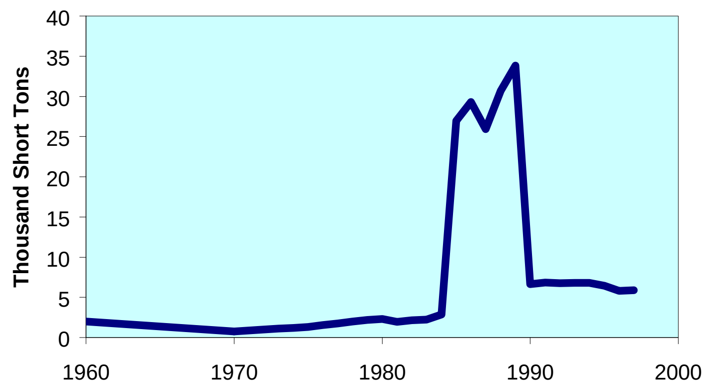
Source: U.S. Environmental Protection Agency. *NET Viewer*.

Most of the VOC emissions from aircraft manufacturing facilities come from solvent utilization in surface coating for aircraft. Estimates of VOC emissions arising from use of solvents in aircraft surface coating are available for 1970 to 1997. The estimates reported in Table 5-5 below include both point and area sources, so the figures do not correspond to the figures reported above by SIC category, which only include point sources.

Table 5-5: VOC Emissions from Solvent Utilization in Surface Coating for Aircraft (Point and Area Sources), 1970-1997

Year	Thousand Short Tons
1960	2
1970	1
1975	1
1980	2
1985	27
1986	29
1987	26
1988	31
1989	34
1990	7
1991	7
1992	7
1993	7
1994	7
1995	6
1996	6
1997	6

Figure 5-1: VOC Emissions from Solvent Utilization in Surface Coating for Aircraft



Source: U.S. Environmental Protection Agency. *National Air Pollutant Emissions Trends Report, 1900-1997* (Table A-3).

Reports from Large Manufacturing Facilities

Reports of criteria pollutant emissions from individual large manufacturing facilities are compiled in EPA's AIRS database. These data are not complete because they do not include information from all manufacturing facilities or allow consistent tracking of trends. They do, however, provide a basis for comparing the contribution of aircraft manufacturing facilities to that of other industrial facilities.

Table 5-6: VOC Emissions from Aircraft and Parts Manufacturing Facilities reported to AIRS

Industry Type (SIC)	Number of Facilities Reporting	Percent of Total Facilities	Pollutant Emissions (tons/year)	Percent of Total Emissions
3721 - Aircraft	14	0.36%	4,339	0.24%
3724 - Aircraft Engines & Engine Part	1	0.03%	140	0.01%
3728 - Aircraft Equipment, Nec	6	0.16%	2,003	0.11%
TOTAL - Aircraft and Parts Manufacture	**21**	**0.55%**	**6,482**	**0.36%**

Source: U.S. Environmental Protection Agency, Office of Air and Radiation. *AIRS Database.* January 1999.

Table 5-7: CO Emissions from Aircraft and Parts Manufacturing Facilities reported to AIRS

Industry Type (SIC)	Number of Facilities Reporting	Percent of Total Facilities	Pollutant Emissions (tons/year)	Percent of Total Emissions
TOTAL - Aircraft and Parts Manufacture	**0**	**0%**	**0**	**0%**

Source: U.S. Environmental Protection Agency, Office of Air and Radiation. *AIRS Database*. January 1999.

Table 5-8: NO_2 Emissions from Aircraft and Parts Manufacturing Facilities reported to AIRS

Industry Type (SIC)	Number of Facilities Reporting	Percent of Total Facilities	Pollutant Emissions (tons/year)	Percent of Total Emissions
3721 - Aircraft	7	0.15%	1200	0.01%
3724 - Aircraft Engines & Engine Part	8	0.17%	2319	0.03%
3728 - Aircraft Equipment, Nec	1	0.02%	193	0%
TOTAL - Aircraft and Parts Manufacture	**16**	**0.34%**	**3712**	**0.04%**

Source: U.S. Environmental Protection Agency, Office of Air and Radiation. *AIRS Database*. January 1999.

Table 5-9: SO_2 Emissions from Aircraft and Parts Manufacturing Facilities reported to AIRS

Industry Type (SIC)	Number of Facilities Reporting	Percent of Total Facilities	Pollutant Emissions (tons/year)	Percent of Total Emissions
3721 - Aircraft	2	0.08%	414	0%
3724 - Aircraft Engines & Engine Part	4	0.17%	1542	0.01%
3728 - Aircraft Equipment, Nec	1	0.04%	109	0%
TOTAL - Aircraft and Parts Manufacture	**7**	**0.29%**	**2065**	**0.01%**

Source: U.S. Environmental Protection Agency, Office of Air and Radiation. *AIRS Database*. January 1999.

Table 5-10: PM_{10} Emissions from Aircraft and Parts Manufacturing Facilities reported to AIRS

Industry Type (SIC)	Number of Facilities Reporting	Percent of Total Facilities	Pollutant Emissions (tons/year)	Percent of Total Emissions
3721 - Aircraft	1	0.09%	152	0.03%
TOTAL - Aircraft and Parts Manufacture	**1**	**0.09%**	**152**	**0.03%**

Source: U.S. Environmental Protection Agency, Office of Air and Radiation. *AIRS Database*. January 1999.

WASTES: TOXICS, WASTEWATER, AND SOLID WASTE

Airplane manufacturing and refurbishing processes result in air, water, and solid wastes. Air emissions primarily include VOCs that result from sealing, bonding, painting, depainting, and finishing application processes. These VOCs are generally organic solvents, such as trichloroethylene, 1,1,1-trichloroethane, toluene, xylene, methyl ethyl ketone, methyl isobutyl ketone or methylene chloride, many of which are air toxics or hazardous air pollutants (HAPs). The solvents may be used either as carriers of a compound for application (sealing, bonding, painting, coating) or as strippers of a compound to be removed (depainting, decoating). Air emissions also include combustion products, metal dusts, and abrasives used during metal shaping.[4]

Wastewater is produced as a byproduct of many metal shaping and finishing processes. Petroleum and oil-based or synthetic metalworking fluids, scrubber effluent, and suspensions may combine with cooling waters during casting and shaping. Wash waters used during metal finishing processes may be contaminated with applied or spilled solvents, water-based paints, organic pollutants, and metals, and toxic constituents such as cyanide. Contamination of used metalworking and machining fluids produces other liquid wastes in addition to wastewater.[5]

Solid wastes are produced during metal shaping and finishing. Solid wastes include scrap metal, off-specification products, paint chips, molding sand, metal-contaminated dust, slag, and wastewater treatment sludges.[6] Table 5-11 summarizes the various wastes that result from aircraft manufacturing and refurbishing activities.

[4] U.S. Environmental Protection Agency, Office of Compliance. *EPA Office of Compliance Sector Notebook Project: Profile of the Aerospace Industry.* August 1998, p. 35.
[5] U.S. Environmental Protection Agency, Office of Compliance. *EPA Office of Compliance Sector Notebook Project: Profile of the Aerospace Industry.* August 1998, pp. 35-36.
[6] U.S. Environmental Protection Agency, Office of Compliance. *EPA Office of Compliance Sector Notebook Project: Profile of the Aerospace Industry.* August 1998, pp. 36-37.

Table 5-11: Wastes Associated with Airplane Manufacturing Processes

Process	Air toxic waste	Wastewater & other fluid wastes	Solid waste
Metal shaping	Solvents	Acid/alkaline wastes, wastewater with oils, grease, and metals; solvents	Scrap metal
Grinding/polishing		Wastewater with oil, grease, and metals	
Plating	Solvents and cleaners	Wastewater with acids/alkalines, cyanides, solvents	
Painting	Paint overspray, solvents	Wastewater with paint and stripping solutions	
Cleaning, depainting, and vapor degreasing	Solvents, acid aerosols	Wastewater with acids/alkalines, solvents	
Chemical milling	Maskants containing HAPs	Waste maskant	Waste maskant
Metal finishing	HAP emissions from processing solutions	Wastewater with cyanide, acids/alkalines	Heavy metal sludges
Coating	HAP emissions from solvents	Waste paint; waste solvent	
Depainting	VOC emissions from paints		Stripper and paint contaminated sludges, paint chips, blasting media
Painting	VOC emissions from paint	Waste paint, thinners, solvents, resins (may contaminate water or soil)	

Sources: Adapted from U.S. Environmental Protection Agency, Office of Compliance. *EPA Office of Compliance Sector Notebook Project: Profile of the Aerospace Industry.* August 1998.

Manufacturers discharge toxic byproducts by releasing the chemicals on-site or transferring it off-site. On-site releases to air occur as either stack emissions—which are through confined air streams, such as stacks or vents—and fugitive emissions, which include equipment leaks, evaporative losses from surface impoundments and spills, and releases from building ventilation systems. Surface water releases may include releases to rivers, lakes, oceans, and other bodies of water. Releases to land may include landfills, surface impoundments, and other types of land disposal within the boundaries of the reporting facility. Underground injection is a contained release of a fluid into a subsurface well for the purpose of waste disposal.

Off-site transfers represent a movement of the chemical away from the reporting facility. Except for off-site transfers for disposal, these quantities do not necessarily represent entry of the chemical into the environment. Chemicals are often shipped to other locations for recycling, energy recovery, or treatment. Transfers often are to publicly owned treatment works (POTWs). Wastewaters are transferred through pipes or sewers to a POTW, where treatment or removal of a chemical from the water depends upon the nature of the chemical and treatment methods used. Some chemicals are destroyed in treatment. Others evaporate into the atmosphere. Some are removed but are not destroyed by treatment and may be disposed of in landfills.

FACTORS THAT AFFECT IMPACT

- Number of aircraft built
- Amount of chemicals used per aircraft
- Efficiency in mitigation efforts
- Types of chemicals released–toxicity
- Population density–extent of exposure
- Environmental conditions–climate, topography, or hydrogeology affecting fate and transport of chemicals into the environment

INDICATORS OF ENVIRONMENTAL IMPACT

Toxic Releases

No data on human health impacts, such as increased incidence of cancer from toxics, or habitat and species impacts are available. According to the 1996 Toxic Release Inventory, 170 aircraft-related manufacturing facilities (SIC Codes 3721, 3724, and 3728) reporting to TRI released nearly 8.0 million pounds of toxic pollutants to the environment in 1996, as shown in the table below.

Table 5-12: Toxic Chemicals Released from Aircraft-Related Manufacturing Facilities, 1996 (pounds per year)

SIC	Industry Type	On-Site Releases	Off-Site Releases (Transfer to Disposal)	Total Quantity Released to the Environment
3721	Aircraft	4,280,481	62,547	4,343,028
3724	Aircraft Engines & Engine Parts	644,882	430,432	1,075,314
3728	Aircraft Parts & Equipment, nec	2,412,299	120,680	2,532,979
-	TOTAL	**7,337,662**	**613,659**	**7,951,321**

Note: On-site releases from Section 5 of Form R. Off-site releases from Section 6 of Form R.

Source: U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics. *1996 Toxics Release Inventory Public Data Release – 10 Years of Right-to-Know: Industry Sector Analyses.* December 1998 (Table 14-3).

Total production-related waste for aircraft-related manufacturing totaled 33.1 million pounds of toxic chemicals in 1996. Of the total production-related toxic waste, 25 percent underwent on-site waste-management (either recycling, use for energy recovery, or treatment on-site) and 51 percent was transferred off-site for waste-management.

Source: U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics. *1996 Toxics Release Inventory Public Data Release – 10 Years of Right-to-Know: Industry Sector Analyses.* December 1998 (Table 14-9).

The top 10 TRI releasing facilities reporting only 372 SIC codes to TRI are listed in the table below:

Table 5-13: Top 5 TRI Releasing Facilities Reporting Only 372 SIC Codes to TRI, 1996

Rank	Facility	SIC Code reported	Total TRI Releases (lbs.)
1	Boeing Commercial Airplane, Everett, WA	3721	784,581
2	Chem-fab Corp., Hot Springs, AR	3728	433,630
3	Raytheon Aircraft Co., Wichita, KS	3721	393,324
4	Douglas Aircraft Co., Long Beach, CA	3721	347,420
5	Pemco Aeroplex Inc., Birmingham, AL	3721	330,130

Source: U.S. Environmental Protection Agency. *Toxics Release Inventory Database, 1996.*

Most toxic releases from aircraft-related manufacturing facilities were emitted to the air. Because chemicals have been added to the Toxic Release Inventory (TRI), deleted, or redefined over time, the following table reports only releases of "core" chemicals required to be reported in all years, 1988-1996.[7] Releases of core chemicals dropped by 33 million pounds — an 82 percent reduction — between 1988 and 1996.

Table 5-14: Toxic Chemicals (Core) Released from Aircraft-Related Manufacturing Facilities (SIC 3721, 3724, 3728), 1988-1996 (thousands of pounds per year)

Year	On-site Releases					Off-site	Total
	Air	Water	Under-ground injection	Direct to land	Total On-site Releases	Releases	Releases to the Environment
1988	**35,626.1**	**33.4**	**59.5**	**171.1**	**35,890.0**	**4,380.1**	**40,270**
1994	**10,631.5**	**6.2**	**0.0**	**2.3**	**10,640.0**	**656.5**	**11,297**
1995	**9,068.6**	**9.3**	**-**	**6.4**	**9,084.2**	**492.7**	**9,577**
1996	**6,809.2**	**5.2**	**-**	**60.6**	**6,875.0**	**306.0**	**7,181**

U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics. *1996 Toxics Release Inventory Public Data Release – 10 Years of Right-to-Know: Industry Sector Analyses.* December 1998 (Table 14-14).

[7] Tables for 1988 to 1996 include only chemicals that were reportable in all years for 1988 to 1996. These tables do not include, for example, chemicals added in 1990, 1991, 1994, or 1995. Because non-fibrous forms of aluminum were removed from the list in 1989, aluminum oxide is not included. Reporting definitions for ammonia, hydrochloric acid and sulfuric acid have also changed, and are not included in multi-year comparisons. The set of "core" chemicals differs depending on which years are being examined, so the figures in this table may not equal those in other tables that use different years.

5.3 AIR TRAVEL

Transport of air passengers and air cargo has increased significantly over the past few decades, particularly since deregulation of the airline industry. Passenger miles traveled on airplanes have increased more than ten-fold between 1960 to 1996, from 33.4 billion miles in 1960 to 445.2 billion in 1996. This dramatic increase in passenger travel has been matched by even more dramatic increases in freight transport by domestic air carriers. Ton miles of freight transported by domestic air carriers has increased from approximately 553 million ton miles in 1960 to 12.9 billion ton-miles in 1996.[8]

The majority of air travel occurs at large airports located in large metropolitan areas. Over half of all air passenger enplanements in the U.S. occurred at only seventeen airports. The largest of these airports in terms of passengers enplaned in 1996 were: Chicago (O'Hare), Atlanta (Hartsfield), Dallas/Ft. Worth, Los Angeles, and San Francisco.[9]

Noise from aircraft is perhaps the most widely recognized adverse environmental impact from air transportation. Other impacts of air travel include emissions of criteria air pollutants, greenhouse gases, and toxics. In addition, aircraft may release hazardous materials as a result of incidents on the ground or in the air.

CRITERIA AIR POLLUTANTS

DESCRIPTION OF IMPACT

Carbon monoxide (CO), sulfur oxides (SO_x), nitrogen oxides (NO_x), volatile organic compounds (VOC), and particulate matter (PM) are all byproducts of the combustion process. Although aircraft only account for a small percent of criteria pollutants emitted nationally, they are unique in that they emit pollutants at a wide range of altitudes. The environmental significance of criteria pollutants varies depending on the altitude of emissions and exposure.

At ground level, these pollutants affect the environment, health, and welfare by causing respiratory and other illnesses, reduced visibility, and soiling and corrosion of materials. They also adversely affect ecosystems, damage to crops, and harm terrestrial and aquatic plants and animals. In the upper atmosphere, VOCs, NO_x and water vapor contribute to global warming (see below).

It is also believed that the dumping of jet fuel can cause severe hydrocarbon pollution, which contributes toward global warming. Fuel dumping is typically done above 10,000 feet so that the fuel will evaporate before reaching the ground. However, scientists believe that even small amounts of pollution at that altitude can be more serious than if released at lower levels.

Although aircraft emissions continue to contribute to criteria air pollutants, the industry has applied procedures that should lower the average pollution generated by aircraft of comparable

[8] U.S. Department of Transportation, Bureau of Transportation Statistics. *National Transportation Statistics 1998.* (Tables 1-10 and 1-11).
[9] U.S. Department of Transportation, Bureau of Transportation Statistics. *National Transportation Statistics 1998.* (Table 1-13).

size and design over the past twenty years. The air travel industry has increased fuel efficiency by lowering cruising speeds, relying on computer optimization, and keeping aircraft exterior equipment stowed during flight.[10] Such changes may moderate the growth rate of aircraft emissions.

The quantity of pollutants emitted by aircraft is a function of aircraft type and engine, mode of operation, and time spent in each mode. For instance emissions during landing and take-off (LTO) modes depend on the duration of each operating mode. HC and CO emissions are very high when the aircraft is in taxi-idle mode and emissions fall when the aircraft moves into higher power operating modes. NO_x emissions, on the other hand are low when engine power is low, but increase as power level is increased. Particulate emissions are higher at low power rates and improve at higher engine power.

FACTORS THAT AFFECT IMPACT

- Number of air takeoffs/landings and cruise miles
- Type of aircraft and engine
- Landing and take-off cycle (LTO) cycle
- Airport congestion levels
- Altitude of aircraft in cruise mode
- Meteorological conditions

INDICATORS OF ENVIRONMENTAL IMPACT

No data are available on the health or habitat effects of emissions from water-based travel.

Aircraft travel emits a small portion of national emissions of most air pollutants, with the exception of lead. In 1997, aircraft travel was responsible for the following emissions nationwide:

Table 5-15: Criteria Pollutant Emissions from Aircraft Travel, 1997

Pollutant	Quantity Emitted (thousand short tons)	Percent of Total Emissions of Pollutant
Carbon Monoxide (CO)	1,012	1.2%
Nitrogen Oxides (NO_X)	178	0.8%
Volatile Organic Comp. (VOCs)	187	1.0%
Sulfur Dioxide (SO_2)	12	0.1%
Particulate Matter (PM_{10})	41	0.1%
Particulate Matter ($PM_{2.5}$)	29	0.3%
Lead (Pb)	0.503	12.8%

*Note: Percentage of emissions from traditionally inventoried sources (does not include agriculture and forestry, fugitive dust, or natural sources like windblown dust)

Source: U.S. Environmental Protection Agency. *National Air Pollutant Emission Trends, 1900-1997.*

[10] U.S. Environmental Protection Agency, Office of Compliance. *EPA Office of Compliance Sector Notebook Project: Profile of the Aerospace Industry.* August 1998, p. 25.

Table 5-16: CO Emissions from Aircraft, 1940-1997

Year	Thousand Short Tons
1940	4
1950	934
1960	1,764
1970	506
1980	743
1985	831
1990	904
1991	888
1992	901
1993	905
1994	915
1995	942
1996	949
1997	1,012

Source: U.S. Environmental Protection Agency, *National Air Pollutant Emissions Trends, 1900-1997* (Table A-1).

Figure 5-2: CO Emissions from Aircraft

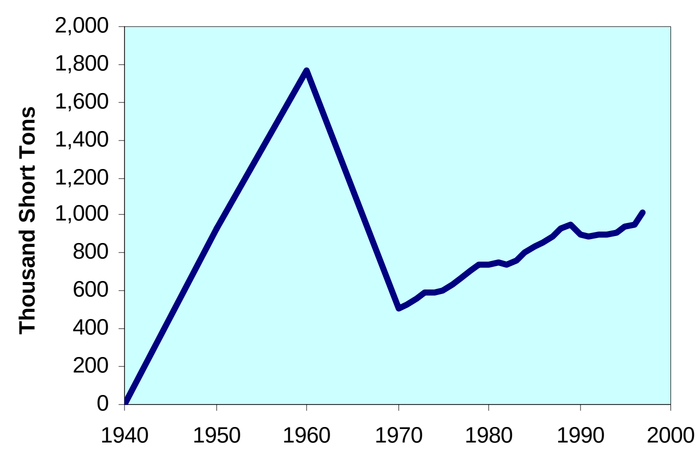
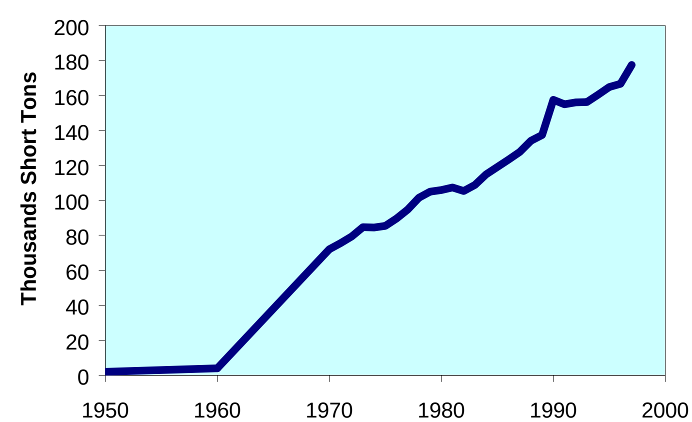


Table 5-17: NO_X Emissions from Aircraft, 1940-1997

Year	Thousand Short Tons
1940	NA
1950	2
1960	4
1970	72
1975	85
1980	106
1985	119
1990	158
1991	155
1992	156
1993	156
1994	161
1995	165
1996	167
1997	178

Figure 5-3: NO_X Emissions from Aircraft

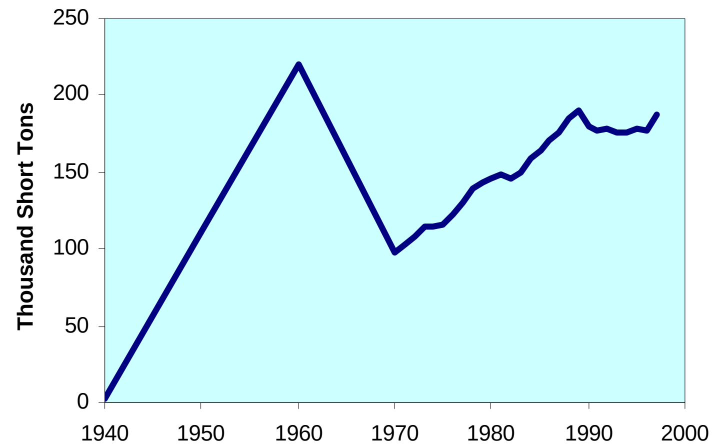


Source: U.S. Environmental Protection Agency, *National Air Pollutant Emissions Trends, 1900-1997* (Table A-2).

Table 5-18: VOC Emissions from Aircraft, 1940-1997

Year	Thousand Short Tons
1940	3
1950	110
1960	220
1970	97
1975	116
1980	146
1985	165
1990	180
1991	177
1992	179
1993	176
1994	176
1995	178
1996	177
1997	187

Figure 5-4: VOC Emissions from Aircraft

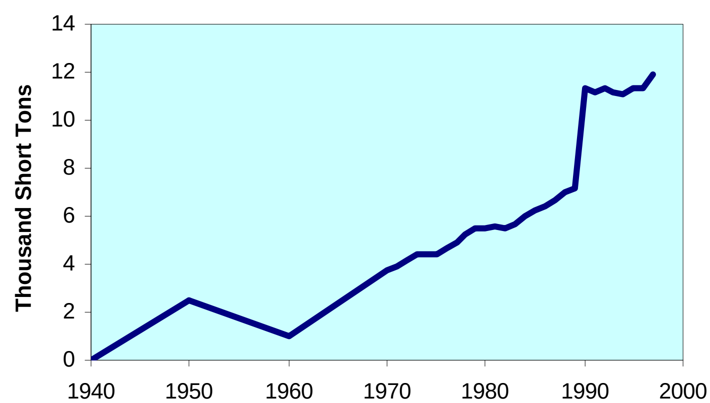


Source: U.S. Environmental Protection Agency, *National Air Pollutant Emissions Trends, 1900-1997* (Table A-3).

Table 5-19: SO_2 Emissions from Aircraft, 1940-1997

Year	Thousand Short Tons
1940	0
1950	3
1960	1
1970	4
1975	4
1980	6
1985	6
1990	11
1991	11
1992	11
1993	11
1994	11
1995	11
1996	11
1997	12

Figure 5-5: SO_2 Emissions from Aircraft



Source: U.S. Environmental Protection Agency, *National Air Pollutant Emissions Trends, 1900-1997* (Table A-4).

Table 5-20: PM$_{10}$ Emissions from Aircraft, 1940-1997

Year	Thousand Short Tons
1940	0
1950	NA
1960	40
1970	21
1975	26
1980	33
1985	37
1990	44
1991	44
1992	45
1993	43
1994	41
1995	40
1996	40
1997	41

Source: U.S. Environmental Protection Agency, *National Air Pollutant Emissions Trends, 1900-1997* (Table A-5).

Figure 5-6: PM$_{10}$ Emissions from Aircraft

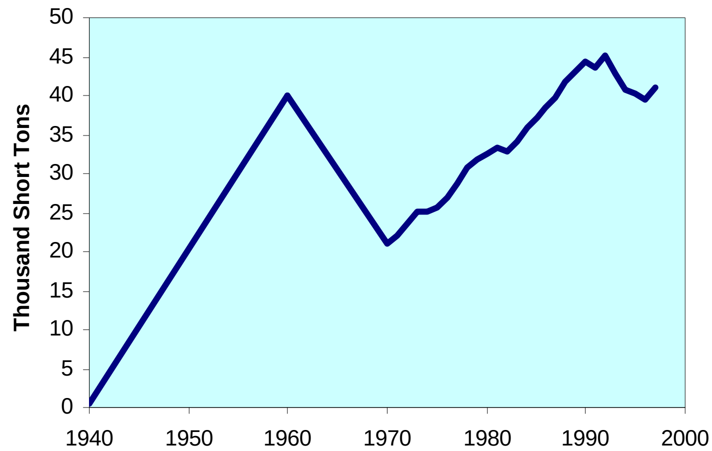


Table 5-21: PM$_{2.5}$ Emissions from Aircraft, 1990-1997

Year	Thousand Short Tons
1990	31
1991	31
1992	32
1993	30
1994	29
1995	28
1996	28
1997	29

Source: U.S. Environmental Protection Agency, *National Air Pollutant Emissions Trends, 1900-1997* (Table A-6).

Figure 5-7: PM$_{2.5}$ Emissions from Aircraft

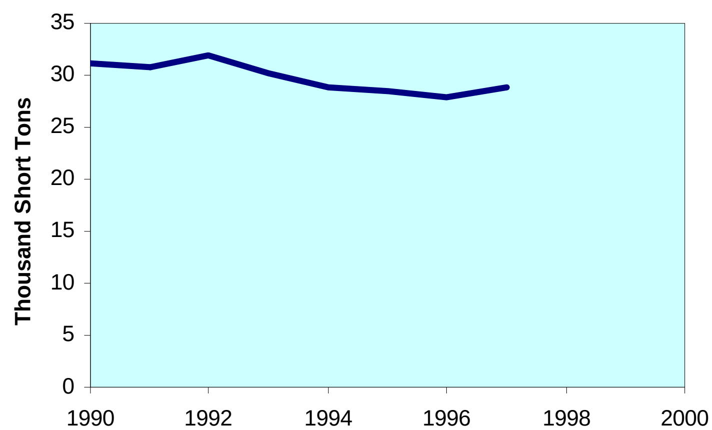
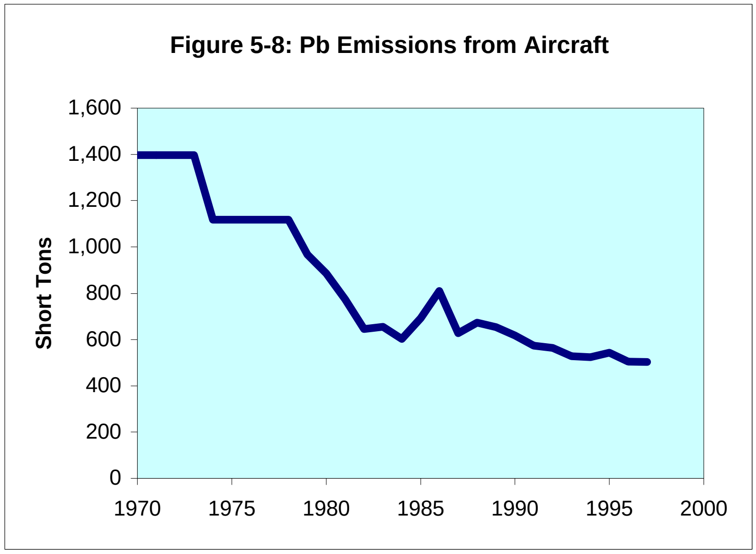


Table 5-22: Lead Emissions from Aircraft Travel, 1970-1997

Year	Short Tons
1970	1,397
1975	1,118
1980	885
1985	692
1990	619
1991	574
1992	565
1993	528
1994	525
1995	544
1996	505
1997	503

Source: U.S. Environmental Protection Agency, *National Air Pollutant Emissions Trends, 1900-1997* (Table A-8).



GREENHOUSE GAS EMISSIONS

DESCRIPTION OF IMPACT

Aircraft emit gases and particles directly into the upper troposphere and lower stratosphere where they have an impact on atmospheric composition. Aircraft emit carbon dioxide (CO_2), a major greenhouse gas, through the combustion of fossil fuels. In addition, aircraft emit gases and particles that alter the concentration of ozone and methane, both of which are greenhouse gases.

Aircraft spend most of their time in cruise mode, directly injecting gases into the higher levels of the atmosphere. Aircraft NO_x emissions are more effective at producing ozone in the upper troposphere than an equivalent amount of emissions at the surface, and increases in ozone in the upper troposphere are more effective at increasing radiative forcing than increases at lower altitudes. On the other hand, aircraft NO_x emissions are expected to decrease the concentration of methane. Aircraft sulfur and water emissions also tend to deplete ozone in the stratosphere, partially offsetting the NO_x-induced ozone increases. The net effect warms the Earth.

Aircraft also trigger formation of condensation trails (called contrails), which tend to warm the Earth's surface. Water vapor emissions also may lead to increases in the formation of high altitude (cirrus) clouds, which tend to warm the Earth. Extensive cirrus clouds have been observed to develop after the formation of persistent contrails.[11]

FACTORS THAT AFFECT IMPACT

- Number of aircraft operations
- Type of aircraft/engine type

[11] Intergovernmental Panel on Climate Change (IPCC). "Aviation and the Global Atmosphere." A Special Report of Working Groups I and III of the IPCC. San José, Costa Rica: April 1999.

- Altitude of aircraft in cruise mode
- Airport congestion levels

INDICATORS OF ENVIRONMENTAL IMPACT

The domestic air transportation industry consumes over one billion gallons of fuel per month (ATA, 12/16/1998).[12]

Carbon Dioxide Emissions

Fossil fuel combustion in air travel was responsible for about 13 percent of CO_2 emissions from transportation, or about 4 percent of carbon dioxide emissions from fossil fuel combustion nationwide.[13]

Table 5-23: Carbon Dioxide Emissions from Fossil Fuel Combustion in Air Travel (Million Metric Tons of Carbon)

Year	Jet Fuel					Aviation Gasoline	Total Air Travel
	General Aviation	Domestic Carriers	Internat'l Carriers	Military Aircraft	Total Jet Fuel	General Aviation	
1990	1.7	32.0	5.1	16.3	**55.1**	**0.8**	**55.9**
1991	1.5	29.6	5.1	16.9	**53.1**	**0.8**	**53.9**
1992	1.3	30.5	5.3	15.2	**52.3**	**0.8**	**53.1**
1993	1.3	30.9	5.3	15.2	**52.7**	**0.7**	**53.4**
1994	1.2	32.0	5.5	16.1	**54.8**	**0.7**	**55.5**
1995	1.4	32.8	5.7	14.3	**54.2**	**0.7**	**54.9**
1996	1.5	34.2	6.0	15.0	**56.7**	**0.7**	**57.4**

Source: U.S. Environmental Protection Agency, Office of Policy, Planning and Evaluation. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1996.* March 1998 (Table 2-6).

Nitrous Oxide and Methane Emissions

Aircraft emit a small amount of nitrous oxide and methane — less than 0.05 million metric tons of carbon equivalent per year.

[12] http://www.air-transport.org/data/ and http://www.air-transport.org/data/fuel.htm, Dec.16, 1998.
[13] Carbon dioxide emissions from fuel combustion in 1996 are estimated at: 57.4 million metric tons of carbon (MMTCE) for air transportation; 445.5 MMTCE for transportation as a whole; 1,450.3 for all sources. Source: U.S. Environmental Protection Agency. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1996.* March 1998 (Table 2-6).

Table 5-24: Nitrous Oxide and Methane Emissions from Aircraft Travel, 1996

Pollutant	Thousand metric tons of gas	Million metric tons of carbon equivalent
Methane (CH_4)	6	<0.05
Nitrous Oxide (N_2O)	<0.5	<0.05

Source: U.S. Environmental Protection Agency, Office of Policy, Planning and Evaluation. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1996.* March 1998 (Tables 2-12, 2-13, 2-14, 2-15).

NOISE

DESCRIPTION OF IMPACT

Noise is the most frequently cited and recognized environmental impact from aircraft. The widespread introduction of jet aircraft in the 1960s and the tremendous growth in airline traffic after deregulation in 1978 resulted in a considerable increase in aircraft noise through the late 1970s. Documented adverse effects of high levels of aviation noise include communication disruption, sleep interference and annoyance.

The primary noise abatement focus of the Federal Aviation Administration (FAA) has been to control noise at its source — the aircraft and its engines. Regulations define three classes of aircraft in terms of their noise levels:

- Stage 1: aircraft certified before 1969 that do not meet the noise standards issued in that year
- Stage 2: aircraft meeting the 1969 standards
- Stage 3: aircraft complying with the latest standards issued in 1977

Because of the long operating life of commercial jets, the FAA issued a rule in 1976 to phase out all Stage 1 aircraft by 1985. Although all aircraft designs certified after March 1977 had to meet Stage 3 noise standards, Stage 2 designs continued to be manufactured until 1988. The phase out of Stage 2 aircraft was established as national policy by the Airport Noise and Capacity Act of 1990, which requires the complete phaseout of Stage 2 aircraft over 75,000 pounds by December 31, 1999. These efforts are expected to significantly reduce exposure to noise levels of Day-Night Sound Level (DNL) 65 dB or above.[14] FAA considers all land uses to be noise compatible below DNL of 65 dB. Areas with DNL above 65 dB are considered incompatible for residential uses, but may be compatible for other uses, such as commercial and manufacturing areas.

Other approaches to resolve aviation noise include noise control programs involving the specification of flight paths and timing of aircraft operations, as well as efforts to reduce the sensitivity of noise impacted areas. The Aviation Safety and Noise Abatement Act of 1979 (ASNA) was the first Federal legislation specifically addressing airport noise problems. It provided the basis for the FAA's noise compatibility planning program, which the FAA initiated in 1981. This program seeks to reduce the sensitivity of noise impacted areas by assisting airport operators and the Federal government in influencing control over development around airports. It includes such compatible land use actions as purchases of heavily impacted land areas, acquisition of noise or development easements, and preempting or replacing noise sensitive uses

[14] DNL represents an energy-averaged sound level for a 24-hour period measured from midnight to midnight after adding 10 decibels to nighttime noise events (between 10 PM and 7 AM).

through zoning and other land use controls. Soundproofing to reduce noise sensitivities inside buildings can be applied under any of these land use strategies.

FACTORS THAT AFFECT IMPACT

- Number of aircraft operations
- Population in area affected by aircraft noise
- Engine type
- Aircraft flight path
- Aircraft glide path

INDICATORS OF ENVIRONMENTAL IMPACT

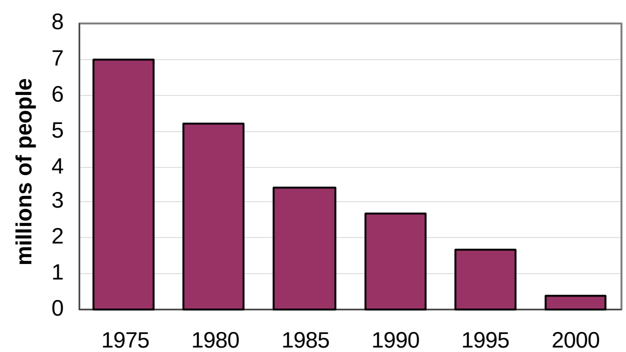
The population exposed to day-night noise level (DNL) of 65 dB or greater from aircraft is estimated to have fallen from approximately 7.0 million to less than 1.7 million, largely due to phase out of Stage 2 aircraft.

Table 5-25: Population Exposed to DNL 65 dB from Aircraft

Year	Population in Millions
1975	7.0
1980	5.2
1985	3.4
1990	2.7
1995	1.7*
2000	0.4*

*Prediction based on Stage 3 implementation

Figure 5-9: Population Exposed to DNL 65 dB from Aircraft



Source: U.S. Department of Transportation, Federal Aviation Administration. *Reprint of Preamble to the Amendments to PART91 Stage 2 Aircraft Phaseout.* 1995.

Exposure to high levels of aircraft noise occurs in areas near busy airports. The following table shows estimates of the population exposed to levels of noise over 65 DNL near the nation's busiest airports, based on environmental documents. Many of the estimates have not been updated.

Table 5-26: Population Exposed to 65 DNL at 30 Busiest Airports

Rank[1]	Airport	Population	Base Year	Data Source
1	O'Hare	209,890	1988	Part 150
2	Atlanta-Hartsfield	80,000	1984	Part 150
3	Dallas-Ft. Worth	16,834	1989	DEIS[2]
4	Los Angeles	92,291	1983	other[3]
5	Denver	14,666	1989	EIS[4]
6	San Francisco	44,440	1982	other
7	St. Louis	79,600	1986	Part 150
8	Newark	65,078	1986	other
9	La Guardia	461,749	1986	other
10	Phoenix	30,993	1987	Part 150
11	Greater Pittsburgh	6,634	1984	Part 150
12	Miami	130,000	1985	other
13	Detroit-Wayne Co.	37,510	1986	Part 150
14	Boston-Logan	99,000	1980	other
15	Kennedy	212,210	1980	other
16	Minneapolis-St. Paul	18,554	1987	Part 150
17	Charlotte	13,243	1988	Part 150
18	Memphis	72,780	1985	other
19	Houston Int'l	4,022	1984	EIS
20	Philadelphia	N/A		
21	Washington-National	24,500	1989	other
22	Orlando	3,480	1985	Part 150
23	Honolulu	6,468	1987	other
24	Las Vegas-McCarren	17,090	1987	other
25	Seattle-Tacoma	78,146	1984	Part 150
26	Baltimore-Washington	14,194	1987	other
27	Salt Lake City	3,915	1984	Part 150
28	Cincinnati	2,019	1985	EIS
29	Kansas City	282	1980	81 EIS, p.34
30	Cleveland	28,730	1981	84 part 150, p.82,p.93

Note: [1] Rank in terms of air traffic. Source 'Terminal Area Forecasts' FAA-APO-90-6 July 1990
[2] Draft Environmental Impact Statement
[3] Information obtained directly from airports or other studies.
[4] Environmental Impact Statement

Source: U.S. Department of Transportation, Federal Aviation Administration, Office of Environment and Energy. http://www.rcaanews.org/rcaa/65dnlpop.htm

HAZARDOUS MATERIALS INCIDENTS

DESCRIPTION OF IMPACT

Hazardous materials releases during aviation may occur en route, as well as during the loading/unloading process. Hazardous materials incidents may cause environmental damage such as air and water pollution, damage to fish and wildlife, and habitat destruction. The environmental impact of any given hazardous material release is highly site-specific. It may immediately affect the internal environment of the aircraft and may involve release of the hazardous material and other matter to surrounding air, water, or land. The environmental impact of any specific incident depends on the type and quantity of material released, amount recovered in cleanup, chemical properties (such as toxicity and combustibility), and impact area characteristics (such as climatic conditions, flora and fauna density, and local topography). While the nationwide impact of hazardous materials releases from aviation may be small, any hazardous materials incident may have severe impacts on the flora and fauna in the location of occurrence.

FACTORS THAT AFFECT IMPACT

- Number of incidents
- Quantity of material released
- Toxicity/hazard of materials released
- Effectiveness of cleanup efforts
- Population exposure
- Sensitivity and location of affected ecosystems.

INDICATORS OF ENVIRONMENTAL IMPACT

No statistics were found regarding the number of species or acres nationwide affected by commodity spills or other hazardous materials incidents.

The Hazardous Materials Information System (HMIS) database, maintained by U.S. DOT/RSPA, contains a record of all reported hazardous materials incidents occurring during transport, including type of material spilled, number of injuries/fatalities, and estimated clean up costs. The number of reported incidents in air transport has increased significantly over the 1990s.

Table 5-27: Aviation Hazardous Materials Incident Totals, 1990-1997

Year	Number of Incidents[1]	Gallons Released	Pounds Released	Cubic Feet Released	MilliCuries Released[2]	Clean Up & Product Loss Damages
1990	297	275.87	634.62	0	0	$71,359
1991	299	298.19	110.18	0	0	$62,249
1992	420	175.52	28.45	0	0	$37,967
1993	622	144.69	20.65	0	404.59	$39,890
1994	929	394.78	485.74	0	0	$101,590
1995	812	272.19	52.93	0	0	$65,825
1996	912	563.22	411.92	0	0	$77,375
1997	1,003	438.91	251.71	0.19	0.01	$102,651

[1] Due to multiple classes being involved in a single incident, the totals above may not correspond to the totals in other reports.
[2] MilliCuries (mCi) are a measure of radioactivity.
Source: U.S. DOT, Research & Special Programs Administration (RSPA), Hazardous Materials Information System (HMIS)

Figure 5-10: Aviation Hazardous Materials Incidents, 1990-1997

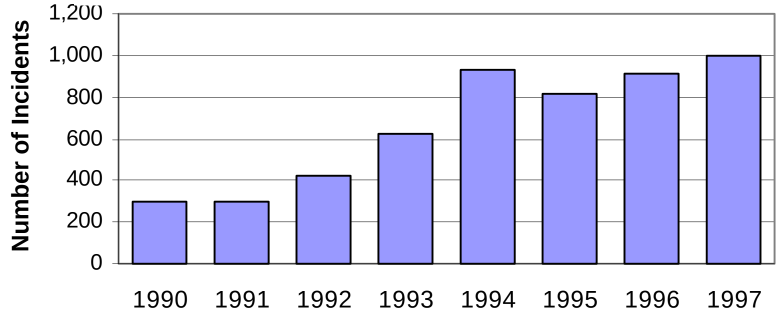


Table 5-28: Aviation Hazardous Materials Incidents, 1997

Hazard Class	Number of Incidents[1]	Gallons Released*	Pounds Released*	Cubic Feet Released*	MiliCuries Released*[2]	Clean Up & Product Loss Damages
Flammable - Combustible Liquid	611	314.79	0	0	0	$47,308
Corrosive Material	185	33.87	65.02	0	0	$42,333
Poisonous Materials	46	63.02	12.12	0	0	$7,467
Other Regulated Material, Class D	44	0	60.11	0	0	$3,200
Nonflammable Compressed Gas	39	12.79	10.7	0.17	0	$825
Miscellaneous Hazardous Material	34	7.7	7.74	0	0	$473
Flammable Gas	31	5.35	0	0.02	0	$515
Oxidizer	11	0.33	12.87	0	0	$25
Organic Peroxide	5	1.03	0.22	0	0	$230
Infectious Substance (Etiologic)	5	0	0.19	0	0	$0
Flammable Solid	4	0	61.75	0	0	$75
Radioactive Material	3	0	0	0	0.01	$0
Explosive No Blast Hazard	2	0	0	0	0	$0
Explosive Mass Explosion Hazard	1	0	15	0	0	$50
Explosive Fire Hazard	1	0	0	0	0	$0
Combustible Liquid	1	0	1	0	0	$150
Spontaneously Combustible	1	0	5	0	0	$0
Dangerous When Wet Material	1	0.02	0	0	0	$0
Other Classes	0	0	0	0	0	$0
TOTALS	1,003	438.91	251.71	0.19	0.01	$102,651

[1] The total for incident number is not equal to the sum of incidents by hazard class, because one incident may be reported under two or more hazard classes. The total for incidents does not double count incidents reported under multiple classes.
[2] MilliCuries (mCi) are a measure of radioactivity.
*Quantities shown are the total of all reported releases. For some incidents, the quantity released is unknown and, therefore, not included in the hazard class or mode totals.
Source: U.S. DOT, Research & Special Programs Administration (RSPA), Hazardous Materials Information System (HMIS)

COLLISIONS WITH WILDLIFE

DESCRIPTION OF IMPACT

Collisions between wildlife and aircraft in the vicinity of airports occur when animals collide with aircraft or get pulled into powerful aircraft engines on runways. Most wildlife collisions with aircraft involve birds, such as starlings, Canadian geese, or gulls, although other animals, such as alligators and even deer have been reported to be struck by aircraft. Wildlife collisions with aircraft are primarily considered a human safety concern because collision events can be dangerous. Since 1995, four aircraft have been destroyed and 70 people have been killed due to collisions between aircraft and wildlife.

In many cases, development and other factors have disrupted migratory patterns of birds, so airports serve as open spaces for wildlife. Federal Aviation Administration (FAA) regulations require airports experiencing wildlife-aircraft conflicts to develop and implement wildlife management plans. The U.S. Department of Agriculture's Wildlife Service (WS) has entered into new cooperative agreements and has continued agreements in place since 1989 to resolve wildlife hazards at airports. In 1997, WS was working on wildlife hazard management projects for 50 airports and military installations.[15] Prevention and control efforts to avoid collisions can include application of repellents, harassing and scaring the animals, or capturing them. Although these efforts may reduce wildlife collisions, they may have other adverse impacts on wildlife.

FACTORS THAT AFFECT IMPACT

- Number of aircraft operations
- Habitat surrounding airport
- Prevention and control efforts by airports

INDICATORS OF ENVIRONMENTAL IMPACT

Although the Federal Aviation Administration (FAA) has monitored voluntary reporting of bird and other wildlife strikes with aircraft since 1965 to determine general patterns in wildlife strikes, no quantitative analyses of these data were conducted until 1995. Since then, data have been examined to ensure consistent, error-free reporting and have been supplemented with non-duplicated strike reports from other sources.

The FAA's database shows 16,949 collision events over the seven year period, 1991 to 1997; however, it is believed that a much larger number of incidents are never reported. Birds were involved in 97 percent of the reported strikes, mammals in 3 percent, and less than one percent involved reptiles. Gulls, blackbirds, raptors, waterfowl, and doves were the most commonly struck bird groups. Deer and coyotes were the most commonly struck mammals.

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[15] U.S. Department of Agriculture, Animal and Plant Health Inspection Service. *Wildlife Services: Program Highlights Fiscal Year 1997.* http://www.aphis.usda.gov/ws/wshl97/health.html

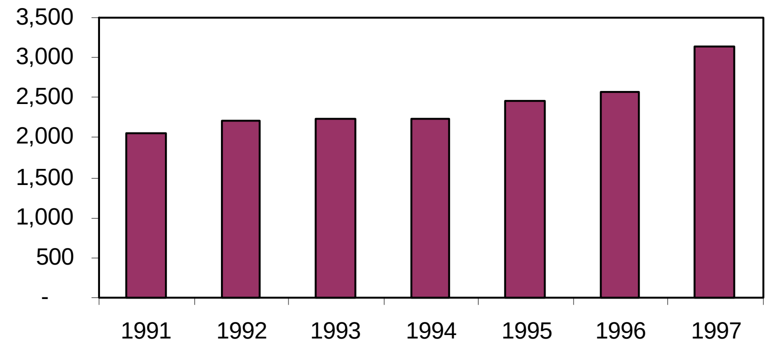
Table 5-29: Collisions between Wildlife and Civil Aircraft in the U.S., 1991-1997

Year	Birds	Mammals	Reptiles	Total
1991	2,024	36	0	**2,060**
1992	2,162	55	1	**2,218**
1993	2,184	55	0	**2,239**
1994	2,169	72	1	**2,242**
1995	2,392	70	8	**2,470**
1996	2,485	88	2	**2,575**
1997	3,061	70	14	**3,145**

Source: U.S. Department of Transportation, Federal Aviation Administration. *Wildlife Strikes to Civil Aircraft in the United States 1991-1997.* September 1998. http://www.faa.gov/arp/arphome.htm

Over the period 1991 to 1997, an average of 2,421 wildlife collisions with aircraft occurred per year. The number of collisions reported has been increasing, with 1997 levels 53% higher than 1991 levels.

Figure 5-11: Number of Reported Strikes between Wildlife and Civil Aircraft



5.4 AVIATION OPERATIONS AND SUPPORT

Aviation operations and support activities encompass both aircraft and airport operations. Aircraft operations include vehicle maintenance, cleaning, fueling and deicing. Airport operations include terminal activities, such as ticketing, baggage handling, food services, concessionaires, and administrative offices. Airport operations also includes maintenance and deicing of runways, operation of ground support equipment, and other site management activities.

Aviation support and operations cause a number of environmental impacts. Airport operations consume energy for heating and cooling and result in air pollutant and greenhouse gas emissions. Airport terminal activities also generate various types of solid waste as paper, plastic, food, and other refuse. In addition, maintenance and support vehicles emit criteria air pollutants and greenhouse gases during operation and toxics may be released during loading and off-loading of hazardous materials carried by aircraft. Aircraft fueling, deicing, tire replacement, fluid and filter changes, cleaning, and refurbishing also result in environmental impacts.[16]

As of April 1997, approximately 16, 280 air transportation establishments existed in the U.S. These include scheduled air transport, nonscheduled air transport, air courier, and airport terminal facilities. Over one third of these facilities are concentrated in five states—California, Texas, Florida, New York, and Illinois.[17] Because air travel continues to increase while only one new major airport has been built since 1974, existing air travel facilities are subject to increasingly heavy usage. Without mitigating practices, such increased use is expected to result in greater environmental impacts to facility land, air, and watersheds.

AIRPORT OPERATIONS

DESCRIPTION OF IMPACT

Airports consume energy to operate lighting, heating and cooling systems, and other electrical equipment. Large airports function like small cities, with passenger services including shops, restaurants, and lounges, in addition to traditional services like baggage handling. Concession shops and food service operations can generate significant quantities of solid waste, such as paper, corrugated cardboard, newspapers, magazines, aluminum, plastic, and glass containers, as well as leftover food. Many airports encompass huge land areas often comparable to the land area of an entire city. Groundskeeping and landscaping activities often involve use of pesticides and herbicides, which can be harmful to wildlife and water quality.

Air pollutants, such as CO, VOC, NO_2, SO_2, PM-10, and Pb, are released during the operation of airport ground support equipment (GSE), fueling of airplanes and GSEs, and airplane maintenance. A variety of GSEs are used to move, service, load, fuel, and power aircraft at airports. GSEs include:

[16] U.S. Environmental Protection Agency. *EPA Office of Compliance Sector Notebook Project: Air Transportation Industry.* February 1998, pp.17-29.
[17] U.S. Environmental Protection Agency. *EPA Office of Compliance Sector Notebook Project: Air Transportation Industry.* February 1998, p. 9.

- Baggage tractors,
- Aircraft tractors,
- Ground power units,
- Air-conditioning units,
- Air start units,
- Baggage conveyors,
- Auxiliary power units (APUs),
- Other secondary GSEs (forklifts, deicing vehicles, lavatory vehicles, fuel vehicles, etc.).

The majority of GSEs have engines that operate on gasoline, diesel, or liquefied petroleum gas (LPG). Like on-road mobile sources, GSEs have tailpipe, evaporative, and crankcase hydrocarbon emissions. NO_x and PM are also emitted from the tailpipe. Their effects on the environment, therefore, are similar to on-road mobile sources.

Fuel vapors may escape into the air during airplane fueling or GSE fueling if fuel lines leak or if complete connections to the vehicle are not established.

FACTORS THAT AFFECT IMPACT

- Number of aircraft support vehicles
- Type of fuel used and size of engine
- Distance traveled by aircraft support vehicles
- Fuel efficiency
- Fuel consumption (airplanes and GSE)
- Hours of flight time (determines maintenance frequency)
- Number of takeoffs and landings (determines maintenance frequency)
- Period of time since prior maintenance (determines maintenance frequency)

INDICATORS OF ENVIRONMENTAL IMPACT

Emissions from Airports, Flying Fields, and Terminals

Quantified information on criteria pollutant emissions from airports, flying fields, and terminals can be extracted from EPA's national emissions inventory. These estimates include only point sources.

Table 5-30: Criteria Pollutant Emissions from Airport, Flying Fields, and Terminals, 1990-1996 (short tons)

Year	VOC	NO_X	CO	SO_2	PM-10
1990	1,129	531	724	614	80
1991	1,415	653	775	610	117
1992	1,583	1,009	877	614	134
1993	1,589	886	856	614	137
1994	1,567	765	835	614	128
1995	1,548	746	829	615	125
1996	1,076	746	829	615	125

Note: Based on SIC code 4581 for airports, flying fields and airport terminal services.

Source: U.S. Environmental Protection Agency. *NET Viewer*.

Reports from Large Point Sources

Reports of criteria pollutant emissions from large point sources, such as airports, are compiled in EPA's AIRS database. These data are not complete because they do not include information from all facilities or allow consistent tracking of trends. They do, however, provide a basis for comparing the contribution of airports and aviation support facilities to other large point sources.

Table 5-31: VOC Emissions from Airports and Aviation Support Facilities reported to AIRS

Industry Type (SIC)	Number of Facilities Reporting	Percent of Total Facilities	Pollutant Emissions (tons/year)	Percent of Total Emissions
4512 - Air Transportation, Scheduled	1	0.03	149	0.01
4581 - Airports, Flying Fields, And Services	3	0.08	716	0.04
4582 - Airports And Flying Fields(1977)	5	0.13	1,068	0.06
TOTAL - Aviation Maintenance, Support, and Operations	**9**	**0.24**	**1,933**	**0.11**

Source: U.S. Environmental Protection Agency, Office of Air and Radiation. *AIRS Database.* January 1999.

Table 5-32: CO Emissions from Airports and Aviation Support Facilities reported to AIRS

Industry Type (SIC)	Number of Facilities Reporting	Percent of Total Facilities	Pollutant Emissions (tons/year)	Percent of Total Emissions
4582 - Airports And Flying Fields(1977)	5	0.98	10,039	0.27
TOTAL - Aviation Maintenance, Support, and Operations	**5**	**0.98**	**10,039**	**0.27**

Source: U.S. Environmental Protection Agency, Office of Air and Radiation. *AIRS Database.* January 1999.

Table 5-33: NO_2 Emissions from Airports and Aviation Support Facilities reported to AIRS

Industry Type (SIC)	Number of Facilities Reporting	Percent of Total Facilities	Pollutant Emissions (tons/year)	Percent of Total Emissions
4581 - Airports, Flying Fields, And Services	2	0.04	418	0
4582 - Airports And Flying Fields(1977)	3	0.07	655	0.01
TOTAL - Aviation Maintenance, Support, and Operations	**5**	**0.11**	**1073**	**0.01**

Source: U.S. Environmental Protection Agency, Office of Air and Radiation. *AIRS Database.* January 1999.

Table 5-34: SO_2 Emissions from Airports and Aviation Support Facilities reported to AIRS

Industry Type (SIC)	Number of Facilities Reporting	Percent of Total Facilities	Pollutant Emissions (tons/year)	Percent of Total Emissions
TOTAL - Aviation Maintenance, Support, and Operations	**0**	**0%**	**0**	**0%**

Source: U.S. Environmental Protection Agency, Office of Air and Radiation. *AIRS Database.* January 1999.

Table 5-35: PM_{10} Emissions from Airports and Aviation Support Facilities reported to AIRS

Industry Type (SIC)	Number of Facilities Reporting	Percent of Total Facilities	Pollutant Emissions (tons/year)	Percent of Total Emissions
TOTAL - Aviation Maintenance, Support, and Operations	**0**	**0%**	**0**	**0%**

Source: U.S. Environmental Protection Agency, Office of Air and Radiation. *AIRS Database.* January 1999.

Emissions from Airport Service Vehicles

Airport ground support equipment emit a small portion of total national emissions of criteria pollutants.

Table 5-36: Criteria Pollutant Emissions from Airport Service Vehicles, 1997

Pollutant	Quantity Emitted (thousand short tons)	Percent of total Emissions of Pollutant
Carbon Monoxide (CO)	184	0.2%
Nitrogen Oxides (NOx)	96	0.4%
Volatile Organic Comp. (VOCs)	17	0.1%
Sulfur Dioxide (SO_2)	NA	NA
Particulate Matter (PM-10)	11	0.0%
Particulate Matter (PM-2.5)	NA	NA
Lead (Pb)	NA	NA

*Note: Percentage of emissions from traditionally inventoried sources (does not include agriculture and forestry, fugitive dust, or natural sources like windblown dust)

Source: U.S. Environmental Protection Agency. *National Air Pollutant Emission Trends, 1900-1997.*

Table 5-37: CO Emissions from Airport Service Vehicles, 1940-1997

Year	Thousand Short Tons
1940	NA
1950	NA
1960	NA
1970	100
1980	144
1985	165
1990	153
1991	151
1992	156
1993	159
1994	163
1995	168
1996	171
1997	184

Source: U.S. Environmental Protection Agency, *National Air Pollutant Emissions Trends, 1900-1997* (Table A-1).

Figure 5-12: CO Emissions from Airport Service Vehicles

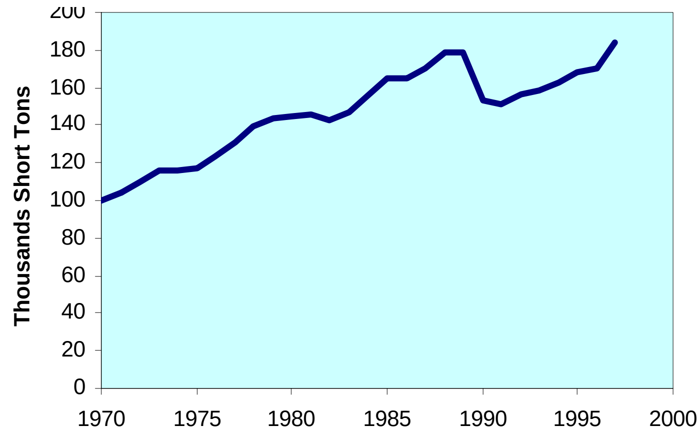
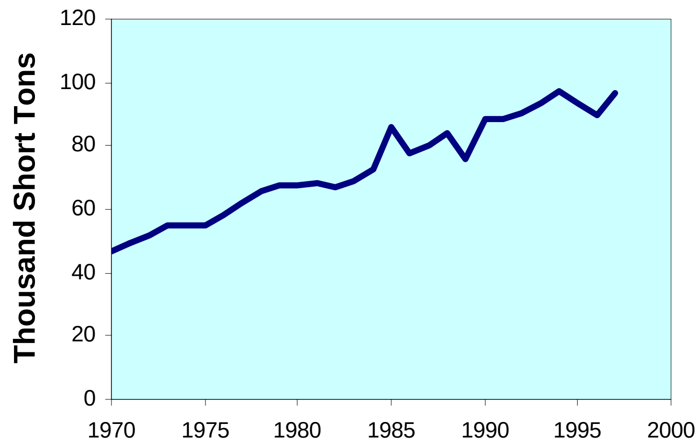


Table 5-38: NO_X Emissions from Airport Service Vehicles, 1940-1997

Year	Thousand Short Tons
1940	NA
1950	NA
1960	NA
1970	47
1975	55
1980	68
1985	86
1990	89
1991	88
1992	90
1993	93
1994	97
1995	94
1996	90
1997	96

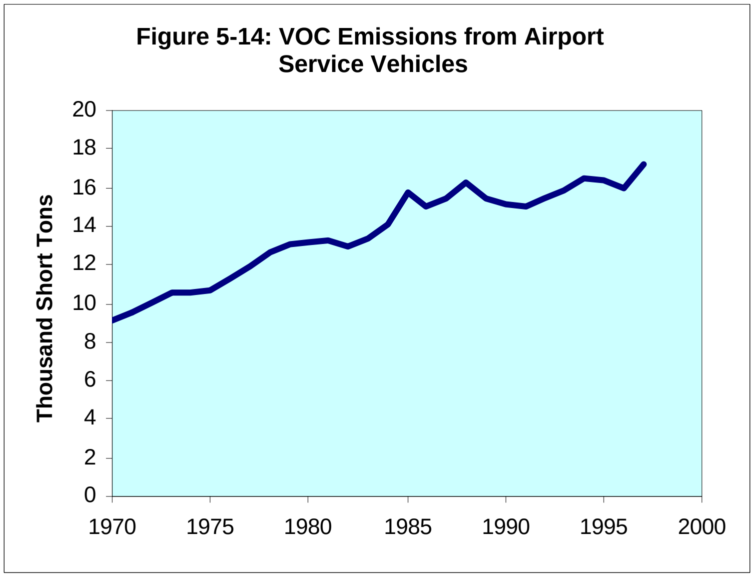
Figure 5-13: NO_X Emissions from Airport Service Vehicles



Source: U.S. Environmental Protection Agency, *National Air Pollutant Emissions Trends, 1900-1997* (Table A-2).

Table 5-39: VOC Emissions from Airport Service Vehicles, 1940-1997

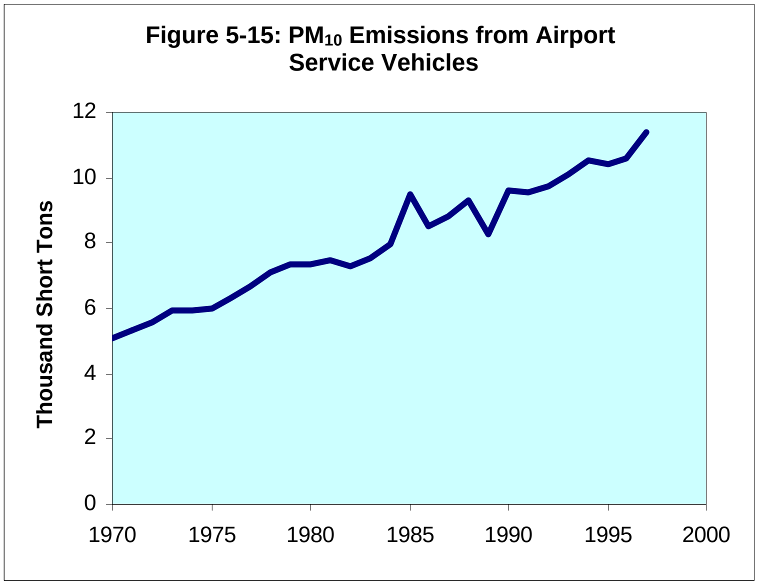
Year	Thousand Short Tons
1940	NA
1950	NA
1960	NA
1970	9
1975	11
1980	13
1985	16
1990	15
1991	15
1992	15
1993	16
1994	16
1995	16
1996	16
1997	17



Source: U.S. Environmental Protection Agency, *National Air Pollutant Emissions Trends, 1900-1997* (Table A-3).

Table 5-40: PM_{10} Emissions from Airport Service Vehicles, 1940-1997

Year	Thousand Short Tons
1940	NA
1950	NA
1960	NA
1970	5
1975	6
1980	7
1985	10
1990	10
1991	10
1992	10
1993	10
1994	11
1995	10
1996	11
1997	11



Source: U.S. Environmental Protection Agency, *National Air Pollutant Emissions Trends, 1900-1997* (Table A-5).

AIRCRAFT AND RUNWAY DEICING

DESCRIPTION OF IMPACT

Airport runways, taxiways, and gate areas are sprayed with deicer and anti-icer to remove and prevent the buildup of ice and snow that would inhibit taxiing, takeoff, and landing.

Deicers are also applied to aircraft to prevent ice from building up on the aircraft itself. Aircraft deicers and anti-icers used in North America have formulations based on glycols such as ethylene glycol, diethylene glycol, and propylene glycol. Generally, deicers are sprayed through hand-held nozzles and hoses onto wings, fuselage, and specific parts of aircraft to remove ice accumulations. Once ice is removed, anti-icing fluids are applied to temporarily prevent re-accumulation of ice. Less commonly, these fluids are applied as the airplane passes through a deicing gantry. The amount of solution required per aircraft ranges from 10 gallons to several thousand gallons. It is estimated that 49 to 80 percent of the deicing/anti-icing solution applied to aircraft falls to the apron.

Runway and taxiway deicers are typically formulated with a combination of urea, glycols, sodium formate and/or potassium acetate. These solutions are used to dislodge snow and ice from the paved surface, facilitate snow and ice removal by plows, and ensure proper friction between aircraft tires and runway surfaces. Sand may be used in the gate area, but is restricted to this use to prevent interference with engine operation.[18]

Spent deicing fluids may or may not be contained and treated before they are released to the environment. Some airport facilities treat deicing and anti-icing wastes as part of its wastewater. Others segregate deicing and anti-icing wastes from general wastewater for separate treatment. FAA permits reuse of deicing solutions under some conditions or resale of fluid for other applications such as windshield wiper fluid. Although separate treatment of deicing/anti-icing solutions technically would permit recycling, costs are currently prohibitive.[19] Some airports release spent deicing and anti-icing fluids directly to surrounding land and water. In these cases, glycol and urea may remain temporarily in snow piles or mix with runway and other local sources of stormwater resulting in on-site puddling and soil infiltration, overland flow, and release to surface waters.

Glycols are biodegradable under normal conditions; their aquatic toxicity is relatively low; and oral toxicity to humans and terrestrial life is also relatively low. However, biodegradation of glycols is so rapid and oxygen demanding that glycol waste can reduce the oxygen available to aquatic life in waters to which deicing and anti-icing fluids are released. Glycols released to surface waters may constitute a minor threat to animal health, because the sweet taste of ethylene glycol may attract animals to deicers and anti-icers contained in puddles. Although none of the glycols used in these fluids have been shown to be harmful to animals, the carcinogen 1,4-dioxane does occur as a trace contaminant in technical grade ethylene glycol.

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[18] U.S. Environmental Protection Agency. *EPA Office of Compliance Sector Notebook Project: Air Transportation Industry.* February 1998, p. 29.
[19] U.S. Environmental Protection Agency. *EPA Office of Compliance Sector Notebook Project: Air Transportation Industry.* February 1998, p. 29.

The urea that is used in runway deicers degrades to ammonia and the ammonia is converted to nitrate. Although both of these processes are slowed considerably at wintertime temperatures, the formation of ammonia and nitrate from urea pose environmental concerns. The toxicity of ammonia to aquatic life is high and excessive nitrate exposure through contaminated drinking water can be hazardous to humans.[20]

FACTORS THAT AFFECT IMPACT

- Amount of aircraft/runway deicing agents applied
- Type of deicing agent used
- Climate/weather conditions (amount of snow, ice, rainfall)
- Amount of high salinity rainfall/snowmelt that reaches bodies of water (based on runoff controls and local geography)
- Depth of groundwater table
- Sensitivity of nearby habitats

INDICATORS OF ENVIRONMENTAL IMPACT

It is estimated that 11.5 million gallons of deicing products are used every year.

Source: D'Itri (ed.). *Chemical Deicers and the Environment.* Lewis Publishers. 1992.

AIRCRAFT MAINTENANCE, FUELING, AND CLEANING

DESCRIPTION OF IMPACT

Aircraft maintenance and support operations generate a number of wastes that may contaminate soil, groundwater, and surface waters. Impacts are associated with the following activities:

- aircraft parts cleaning, lubrication, and fluid changes;
- battery repair and replacement; and
- fueling.

The primary environmental effect of aircraft cleaning is the generation and disposal of wastewater from cleaning aircraft exteriors. Aircraft are cleaned by dry methods or washing with detergent solutions and a water rinse. Small aircraft cleaning typically is carried out using hand held spray nozzles, hoses, and brushes. For larger aircraft, dry polishing generally is used whenever possible, with wet cleaning limited to wheel wells and landing gear. If high-pressure steam cleaners are used, water use may range from 10 to 20 gallons for washing small aircraft and 100 to 200 gallons for large aircraft. Wastewater can contain cleaners, metals, oil and grease. To prevent the release of untreated wastewater, it usually drains to catch basins where it is mixed

[20] D'Itri (ed.). *Chemical Deicers and the Environment.* Lewis Publishers. 1992.

with other airport wastewater and discharged at an onsite treatment facility or discharged to a publicly owned treatment works (POTW).[21]

Parts cleaning may employ water and detergents or solvents applied directly to the parts or the parts may be submerged in baths. Solvents pose the greatest possibility of environmental pollution because many solvents produce evaporative hazardous air pollutants. They also have the potential to pollute soil and water if released in fluid form during use and may contaminate wastewater generated during cleaning. The major use of solvents for parts cleaning involves hand-wiping of parts; however, parts may also be directly flushed or sprayed with solvents or immersed in a solvent bath.

If handled correctly, battery repair and replacement do not pose a threat to the immediate environment. However, the sulfuric acid contained in batteries has the potential to cause personal injury to workers and to contaminate surrounding soil and water if released during maintenance.

In addition to release of criteria air pollutants discussed earlier, fueling has the potential to pollute soil and water. Fuel spills can occur during fueling or as leakages from improperly maintained storage tanks. Use of vacuum sweepers to contain above ground spills and implementation of EPA tank maintenance requirements limit the potential for contamination of soil and water.[22]

FACTORS THAT AFFECT IMPACT

- Type and level of maintenance operations
- Materials used during maintenance operations
- Wastewater treatment capabilities

INDICATORS OF ENVIRONMENTAL IMPACT

National indicators of the environmental impacts of aircraft maintenance, fueling, and cleaning are not available.

[21] U.S. Environmental Protection Agency. *EPA Office of Compliance Sector Notebook Project: Air Transportation Industry*. February 1998. pp. 23-24.
[22] U.S. Environmental Protection Agency. *EPA Office of Compliance Sector Notebook Project: Air Transportation Industry*. February 1998. pp. 22-23.

5.5 DISPOSAL OF AIRCRAFT AND PARTS

Disposal of aircraft is the last phase in the lifecycle analysis of aviation-related environmental impacts.

SOLID WASTE

DESCRIPTION OF IMPACT

Solid waste from aircraft and ground support equipment disposal includes batteries, tires, brake pads and other used vehicle components. Airplanes are often shifted to other uses or exported when retired from commercial service in the U.S. Exportation, coupled with the longevity of the current fleet of airplanes, results in relatively low rates of scrappage.

FACTORS THAT AFFECT IMPACT

- Number of aircraft scrapped
- Quantity of metals and oil used in operations
- Disposal method/Recovery rate of materials
- Groundwater contamination and seepage prevention measures at the disposal site.

INDICATORS OF ENVIRONMENTAL IMPACT

Data on the amount of waste from aircraft scrappage are unavailable. It is known, however, that aircraft parts make up a very small portion of the national solid waste stream and rates of aircraft scrappage are low.

6. MARITIME ENVIRONMENTAL INDICATORS

This chapter describes the environmental impacts of maritime transportation and presents quantitative indicators available for tracking environmental impacts. Maritime transportation is defined here as all water-based transportation, including travel by freight and military vessels, passenger ferries, and recreational boats. Although recreational boating may not be pursued for a transportation purpose, impacts associated with boating are included here to the extent that indicators were available because boats are a mobile source of emissions and it is difficult to separate out the recreational aspect of any mode. Impacts are described for five categories of maritime activities:

- Construction of Ports and Navigation Improvements
- Vessel and Equipment Manufacture
- Water-based Travel
- Port Operations, Maintenance, and Support
- Disposal of Vessels and Parts

6.1 CONSTRUCTION OF PORTS AND NAVIGATION IMPROVEMENTS

The waterway system in the U.S. consists of coastal and inland ports and inland waterways. There are approximately 360 coastal and inland ports in the U.S., where cargo is transferred to and from vessels. Most of the inland waterway system is made navigable by a series of dams that form slack water pools, and navigation locks that allow vessels to move from one pool to another. The U.S. Army Corps of Engineers owns and/or operates and maintains 275 lock chambers at 230 sites. On the Mississippi River below St. Louis and the Missouri River, navigation is maintained with dikes, groins, and other river training structures.

In order to maintain navigation channels and berthing areas, nearly all waterways require periodic dredging. Dredging is undertaken to increase the depth of waterways to allow passage for large marine vessels. Dredging is associated with several adverse environmental impacts, including degradation of habitats, hydrologic alterations, contaminated sediments, and deterioration of water quality. Dredged material can also be used for beneficial purposes, such as wetland creation and beach nourishment. Development of ports and marinas for recreational boats can also have adverse impacts on habitat and hydrologic resources. These effects are discussed below.

HABITAT IMPACTS FROM DREDGING

DESCRIPTION OF IMPACT

Dredging is the primary infrastructure activity undertaken to improve navigation for water-borne transportation. Two aspects of dredging can cause environmental damage: (1) disturbance and removal of bottom material and (2) disposal of dredged material. Dredging, which involves the mechanical displacement of sediments for the purpose of creating, maintaining, or extending ports and navigational waterways, necessarily disrupts bottom habitats. One study revealed that the immediate effects of dredging on benthic and other animal communities can be substantial, although dredged areas recover if left undisturbed. Maintenance dredging, however, which entails dredging a particular channel periodically to sustain a prescribed depth, can prohibit recovery. Dredging can also alter natural water circulation patterns, which can affect ecosystems in a variety of ways, such as through increased or decreased salinity.[1]

Dredging (and other navigation improvements) results in the accumulation of extensive amounts of material from the bottoms of bodies of water. Disposal of dredged material has the potential to cause far-reaching environmental impacts. There are two major methods of disposal: (1) disposal in open water, and (2) disposal on land. Disposal in open water can alter bottom habitats, decrease water quality, and harm marine organisms. Repeated disposal at a site can form mounds in bottom habitats, because most material sits where it is dumped. Disposal of dredged material in open waters can affect water quality by physical means, such as increasing turbidity, or chemical means, such as raising pollutant concentrations. Open water disposal can harm marine organisms in a number of ways. Benthic organisms can be killed by physical burial under dredged material. A more widespread effect of disposal on marine fauna is uptake of toxics. Contaminants may impact the benthic community even if dredged material is capped, and larger animals may ingest contaminants either directly or indirectly through feeding on smaller animals.[2]

Virtually all ocean dumping occurring today is dredged material.[3] Ocean dumping cannot occur unless a permit is issued under the Marine Protection, Research, and Sanctuaries Act (MPRSA). In the case of dredged material, the decision to issue a permit is made by the U.S. Army Corps of Engineers, using EPA's environmental criteria and subject to EPA's concurrence. EPA is also responsible for designating recommended ocean disposal sites for use under such permits. EPA's environmental criteria under the MPRSA provide that no ocean dumping will be allowed if the dumping would cause significant harmful effects or the material proposed to be dumped is not adequately characterized.[4]

Disposal of dredged material on land can be beneficial or detrimental, depending primarily on the quality of the material. If the material is not contaminated, it can be used for beneficial purposes, such as construction, beach nourishment, land creation, wetland creation, and wetland restoration. Sediments from maintenance dredging are more likely to be contaminated than sediments from new work because they are composed of recent deposits.[5]

Contaminated sediments must be disposed. Disposal of contaminated dredged material on land is highly controversial for many reasons, including its high cost and the possibility of pollution. Contaminants can potentially escape from upland containment facilities and enter groundwater aquifers or surface waters.

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[1] Canter, Larry W. *Environmental Impacts of Water Resources Projects.* Lewis Publishers, Inc. 1985.

[2] U.S. Environmental Protection Agency. *Characteristics and Effects of Dredged Material Disposal in the Marine Environment.* 1989.

[3] In 1972, Congress enacted the Marine Protection, Research, and Sanctuaries Act (MPRSA) to prohibit the dumping of material into the ocean that would unreasonably degrade or endanger human health or the marine environment. The MPRSA was amended in 1988 to ban ocean dumping of industrial waste and sewage sludge.

[4] U.S. Environmental Protection Agency, Region 4, Coastal Programs and Surface Water Quality Grants Section. "Ocean Dumping Program." http://www.epa.gov/region04/waterpgs/water/oceans/odmain.htm

[5] U.S. Environmental Protection Agency. *Characteristics and Effects of Dredged Material Disposal in the Marine Environment.* 1989.

The most commonly considered alternatives for contaminated sediments are (1) placement in confined disposal facilities (CDFs) and (2) capping, an option for containment in subaqueous sites. CDFs are located on land or in areas of relatively sheltered water. Many CDF's are near closure and future locations may include nontraditional areas such as offshore sites. Treatment to reclaim CDF capacity may be promising for certain sites. Capping has significant potential as a disposal alternative, but issues related to its long-term effectiveness and potential application to deeper waters or high-energy environments require additional environmental investigation.[6]

FACTORS THAT AFFECT IMPACT

- Demand for new or expanded waterways
- Size of vessels using ports
- Type of dredge and other construction equipment used
- Successful implementation of various efforts to avoid or mitigate impacts
- Species/habitats in channels
- Type of disposal (e.g., capped, uncapped, contained)
- Location of disposal (land, coastal waters, open ocean)

INDICATORS OF ENVIRONMENTAL IMPACT

WETLANDS LOSS

In 1996, 7 states reported that dredging was a source of wetlands loss. Three states reported that disposal of dredged material was a source of direct wetlands losses in 1996.

Source: U.S. Environmental Protection Agency. *Appendixes from the National Water Quality Inventory:1996 Report to Congress*, http://www.epa.gov/OW/resources/9698/appendix.xls

AMOUNT OF DREDGING

The U.S. Army Corps of Engineers dredges and disposes of about 200 to 300 million cubic yards of material annually from Congressionally-authorized navigation improvement and maintenance projects. In addition, permit applicants (e.g., port authorities, terminal owners, industries, and private individuals) dredge an additional 100 million cubic yards annually from navigation projects. As a result, about 400 million cubic yards of sediment are dredged annually from U.S. waterways.

Source: U.S. Environmental Protection Agency. "Ocean Dumping Program Update." EPA842-F-96-003. 1996. http://www.epa.gov/OWOW/OCPD/oceans/update3.html and Army Corps of Engineers, Navigation Data Center. *Dredging Statistics Database*.

The following table shows quantities dredged annually by the U.S. Army Corps of Engineers, the largest dredger in the U.S (note that port authorities, terminal owners, industries, and private individuals also undertake dredging).

[6] U.S. Army Corps of Engineers. http://www.wes.army.mil/el/dots/doer/fsconsed.html

Table 6-1: Quantities Dredged by the U.S. Army Corps of Engineers, 1990-1998

Year	Quantities of Dredged Material (in thousands cubic yards)
1990	185,652
1991	219,946
1992	235,519
1993	218,249
1994	229,318
1995	198,570
1996	186,873
1997	227,450
1998	219,597

Source: Army Corps of Engineers, Navigation Data Center. *Dredging Statistics Database*. Information compiled as of January 1999.

DISPOSAL/USE OF DREDGED MATERIAL

Each year approximately 60 million cubic yards of dredged material is disposed of in the ocean at designated sites.

Source: U.S. Environmental Protection Agency. "Ocean Dumping Program Update." EPA842-F-96-003. 1996. http://www.epa.gov/OWOW/OCPD/oceans/update3.html

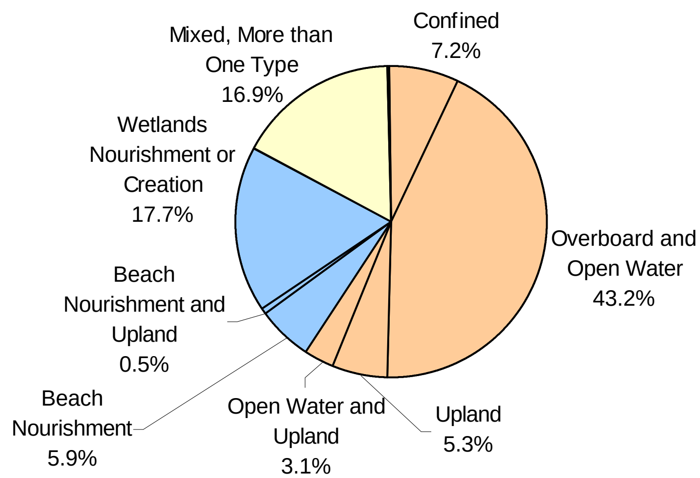
The table below presents information on quantities of dredged materials disposed in various places by the U.S. Army Corps of Engineers. At least 24 percent of disposed material is used for beneficial purposes (beach nourishment, wetlands nourishment or creation).

Table 6-2: Disposal of Dredged Material by the U.S. Army Corps of Engineers, 1998

Type of Material Disposal	Disposal of Dredged Material (thousands of cubic yards)	Percent
Confined	15,710	7.2%
Overboard and Open Water	94,935	43.2%
Upland	11,713	5.3%
Open Water and Upland	6,850	3.1%
Beach Nourishment	12,992	5.9%
Beach Nourishment and Upland	1,011	0.5%
Wetlands Nourishment or Creation	38,810	17.7%
Mixed, More than One Type	37,152	16.9%
Undefined	422	0.2%

Source: Army Corps of Engineers, Navigation Data Center. *Dredging Statistics Database*. Information compiled as of January 1999.

Figure 6-1: Disposal / Use of Material Dredged by Army Corps of Engineers, 1998



The percentage of dredged material in the U.S. that is contaminated enough to require special handling is less than 10 percent and possibly lower than 5 percent, although past estimates have ranged as high as 30 percent.[7]

Source: Cullinane, M. John et al. *Contaminated Dredged Material: Control, Treatment and Disposal Practices*. Noyes Data Corporation, 1990.

The U.S. Army Corps of Engineers considers approximately 3 percent of its dredged material to be highly contaminated and 30 percent to be moderately contaminated.

Source: U.S. Environmental Protection Agency. *Characteristics and Effects of Dredged Material Disposal in the Marine Environment*. 1989.

HABITAT IMPACTS FROM DEVELOPMENT OF PORTS AND MARINAS

DESCRIPTION OF IMPACT

Maritime transportation impinges on coastal, riparian, and other marine habitats through the taking of land to construct and operate ports and marinas. In many cases, ports and marinas sequester and alter extensive natural areas, resulting in degraded ecosystems and loss of habitats. Most marinas primarily serve recreational boaters, although water taxis and ferries also use these facilities in urban areas. It is difficult to attribute the exact share of this impact to transportation since a great deal of coastal development is for recreational purposes.

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[7] Certain ports, however, have reported much higher percentages. For example, MASSPORT reported that a third of its dredged material was contaminated, and the ports of both Jacksonville and San Diego reported that half of their material was contaminated in 1993 (Source: American Association of Port Authorities. *1993 Dredging and Disposal Survey*. 1995).

FACTORS THAT AFFECT IMPACT

- Number of new port and marina facilities constructed
- Level of expansion of existing ports and marinas
- Inappropriate siting of marinas or port facilities

INDICATORS OF ENVIRONMENTAL IMPACT

No national-level outcome indictors are available for the impacts of marinas on the environment. Information about the amount of shoreline acreage developed specifically to support maritime transportation is not available. It is known, however, that there are approximately 10,000 marinas in the U.S.

Source: International Marina Institute, 1991 database.

6.2 MANUFACTURE OF VESSELS AND PARTS

Vessel manufactures can be divided into two industry groups: ship building and repair (SIC code 3731) and boat building and repair (SIC code 3732). The distinction is based primarily on the size of vessels being constructed. There are approximately 598 ship building and repairing facilities (SIC code 3731) in the United States. These facilities construct nonpropelled ships (barges, drilling/production platforms, and floating docks) and large self-propelled ships, including large yachts, dry bulk carriers, tankers, commercial fishing vessels, tugboats, and ferryboats. Ships are produced for military and nonmilitary uses. These facilities are located in 24 states and are concentrated on the coasts, southern Mississippi River, and Great Lakes region.

There are approximately 2,455 boat building and repairing facilities (SIC code 3732) in the United States.[8] These facilities construct outboard and inboard motorboats, sailboats, and canoes, and also are involved in boat repair. These facilities are also concentrated on the coasts, with the most facilities in Florida (465), California (231), and Washington (186).

The U.S. shipbuilding industry currently faces a low volume of orders. Owing to increased global competition, the United States has received less than one percent of worldwide commercial orders for large ocean vessels and no orders for large ocean going cruise ships since 1981. U.S. "first tier shipyards," i.e., those that are capable of handling ships of at least 122 meters (383 ft.), manufactured approximately 77 ships of 100-plus gross tons per year in the mid-1970s. This figure fell to approximately 8 ships total from the late 1980s into the early 1990s. There was a slight upswing in U.S. commercial ship production in 1995 and 1996, however, owing to aging merchant fleets and greater worldwide demand.[9]

In contrast, the number of recreational boats in the U.S. has increased dramatically over the past thirty years. The increase in the vessel fleet provides an indication of the amount of vessel manufacture, but does not signify that new vessels were produced in the United States. Environmental impacts resulting from the manufacture of these vessels include releases of criteria air pollutants and toxics to the air, soil, and water.

CRITERIA AIR POLLUTANTS

DESCRIPTION OF IMPACT

Air pollutants are emitted during a number of different vessel and parts manufacturing processes. Surface preparation operations, which involve use of blasting abrasives, solvent cleaners, paint strippers, and degreasers, can lead to the release of particulates and volatile organic compounds (VOCs). Oxides of nitrogen (NO_x), sulfur dioxide (SO_2), and lead are also released during other processes such as painting, metal plating and surface finishing, machining and metal working, and solvent cleaning and degreasing. The most common VOCs released through the use of

[8] U.S. Department of Commerce, Economics and Statistics Administration, Bureau of the Census. *1992 Census of Manufactures Industry Series: Ship and Boat Building, Railroad and Miscellaneous Transportation Equipment.*

[9] U.S. Environmental Protection Agency. *Profile of the Shipbuilding and Repair Industry*, 1997.

solvents include xylenes, n-butyl alcohol, toluene, methyl ethyl ketone, and methyl isobutyl ketone.

FACTORS THAT AFFECT IMPACT

- Number of vessels built
- Amount of chemicals used per vessel
- Efficiency of controls and efforts to reuse or recycle chemicals and other materials, including pollution prevention efforts
- Types of chemicals released
- Environmental conditions - climate, topography, or hydrogeology affecting fate and transport of chemicals and materials in the environment

INDICATORS OF ENVIRONMENTAL IMPACT

ESTIMATES FROM NATIONAL INVENTORIES

Quantified information on criteria pollutant emissions from ship and boat building and repairing facilities can be extracted from EPA's national emissions inventory. These estimates include only point sources.

Table 6-3: Criteria Pollutant Emissions from Ship and Boat Building and Repairing Facilities, 1990-1996 (short tons)

Year	VOC	NOx	CO	SO2	PM-10
1990	14,106	2,222	245	2,938	1,134
1991	13,723	1,961	211	3,287	831
1992	13,943	1,973	217	3,200	887
1993	13,839	2,049	218	3,102	1,067
1994	13,269	2,212	231	3,628	984
1995	13,423	1,824	219	3,049	934
1996	12,761	1,824	219	3,049	934

Note: Based on following SIC codes--3731 and 3732.

Source: U.S. Environmental Protection Agency. *NET Viewer*.

Pollutant emissions from ship and boat building and repairing facilities by SIC code are presented below:

Table 6-4: Criteria Pollutant Emissions from Ship and Boat Building and Repairing Facilities by SIC Code, 1996 (short tons)

SIC	Industry Type	VOC	NO_x	CO	SO_2	PM-10
3731	Ship building and repairing	5,331	1,779	213	2,992	881
3732	Boat building and repairing	7,430	45	6	57	53
-	TOTAL	12,761	1,824	219	3,049	934

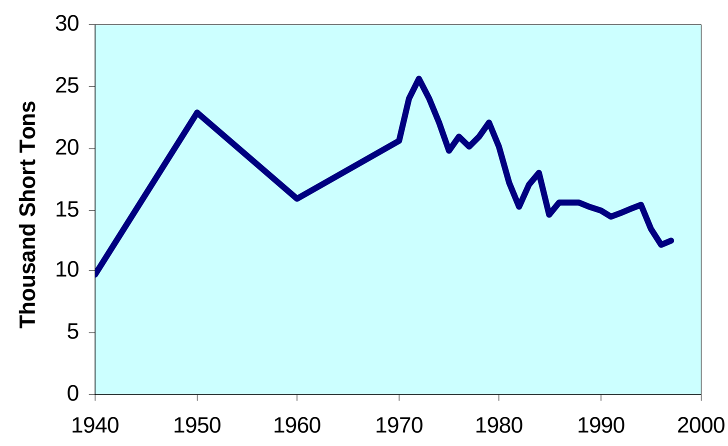
Source: U.S. Environmental Protection Agency. *NET Viewer*.

Most of the VOC emissions from ship and boat building and repairing come from solvent utilization in surface coating for vessels. Estimates of total VOC emissions from solvent use in surface coating are available for 1970 to 1997. The estimates reported below include both point and area sources, so the figures do not correspond to the figures reported above by SIC category, which only include point sources. Solvent use in ship manufacturing is estimated to have released approximately 13,000 short tons of volatile organic compounds (VOC) in 1997.

Table 6-5: VOC Emissions from Solvent Utilization in Manufacture of Large Ships (Point and Area Sources), 1940-1997

Year	Thousand Short Tons
1940	10
1950	23
1960	16
1970	21
1975	20
1980	20
1985	15
1990	15
1991	14
1992	15
1993	15
1994	15
1995	13
1996	12
1997	13

Figure 6-2: VOC Emissions from Solvent Utilization in Manufacture of Large Ships



Source: U.S. Environmental Protection Agency. *National Air Pollutant Emissions Trends Report, 1900-1997* (Table A-3).

REPORTS FROM LARGE MANUFACTURING FACILITIES

Reports of criteria pollutant emissions from individual large manufacturing facilities are compiled in EPA's AIRS database. These data are not complete because they do not include information from all manufacturing facilities or allow consistent tracking of trends. They do, however, provide a basis for comparing the contribution of ship and boat manufacturing facilities to that of other industrial facilities.

Table 6-6: VOC Emissions from Vessel Manufacturing Facilities reported to AIRS

Industry Type (SIC)	Number of Facilities Reporting	Percent of Total Facilities	Pollutant Emissions (tons/year)	Percent of Total Emissions
3731 – Ship Building And Repairing	12	0.31%	2,924	0.16%
3732 – Boat Building And Repairing	20	0.52%	3,411	0.19%
TOTAL – Vessel and Parts Manufacture	**32**	**0.83%**	**6,335**	**0.35%**

Source: U.S. Environmental Protection Agency, Office of Air and Radiation. *AIRS Database.* January 1999.

Table 6-7:CO Emissions from Vessel Manufacturing Facilities reported to AIRS

Industry Type (SIC)	Number of Facilities Reporting	Percent of Total Facilities	Pollutant Emissions (tons/year)	Percent of Total Emissions
TOTAL - Vessel and Parts Manufacture	**0**	**-**	**0**	**-**

Source: U.S. Environmental Protection Agency, Office of Air and Radiation. *AIRS Database*. January 1999.

Table 6-8: NO_2 Emissions from Vessel Manufacturing Facilities reported to AIRS

Industry Type (SIC)	Number of Facilities Reporting	Percent of Total Facilities	Pollutant Emissions (tons/year)	Percent of Total Emissions
3731 - Ship Building And Repairing	3	0.07%	697	0.01%
3732 - Boat Building And Repairing	0	-	0	-
TOTAL - Vessel and Parts Manufacture	**3**	**0.07**	**697**	**0.01**

Source: U.S. Environmental Protection Agency, Office of Air and Radiation. *AIRS Database*. January 1999.

Table 6-9:SO_2 Emissions from Vessel Manufacturing Facilities reported to AIRS

Industry Type (SIC)	Number of Facilities Reporting	Percent of Total Facilities	Pollutant Emissions (tons/year)	Percent of Total Emissions
3731 - Ship Building And Repairing	4	0.17%	2,702	0.02%
3732 - Boat Building And Repairing	0	-	0	-
TOTAL - Vessel and Parts Manufacture	**4**	**0.17%**	**2,702**	**0.02%**

Source: U.S. Environmental Protection Agency, Office of Air and Radiation. *AIRS Database*. January 1999.

Table 6-10: PM_{10} Emissions from Vessel Manufacturing Facilities reported to AIRS

Industry Type (SIC)	Number of Facilities Reporting	Percent of Total Facilities	Pollutant Emissions (tons/year)	Percent of Total Emissions
3731 - Ship Building And Repairing	4	0.35%	799	0.17%
3732 - Boat Building And Repairing	0	-	0	-
TOTAL - Vessel and Parts Manufacture	**4**	**0.35%**	**799**	**0.17%**

Source: U.S. Environmental Protection Agency, Office of Air and Radiation. *AIRS Database*. January 1999.

WASTES: TOXICS, WASTEWATER, AND SOLID WASTE

DESCRIPTION OF IMPACT

The manufacture of ships and boats involves use of a variety of materials and chemicals. During manufacturing, toxic chemicals, wastewater and other fluids, and solid waste are released from vessel manufacturing facilities into the environment. Table 6-10 summarizes the various wastes that result from ship and boat manufacturing and refurbishing activities.

Table 6-11: Wastes Associated with Ship and Boat Manufacturing Processes

Process	Air toxic waste	Wastewater & other fluid wastes	Solid waste
Surface Preparation *Uses abrasives, detergents, solvent paint strippers and cleaners, and caustic solutions*	Particulates and VOCs from solvent cleaners and paint strippers.	Wastewater containing paint chips, cleaning and paint stripping solvents, surface contaminants, and oil residues from bilges and cargo tanks	Paint chips, spent abrasives, surface contaminants, and cargo tank residues.
Metal Plating and Surface Finishing *Uses plating metals, cyanide solutions, cleaning solvents, rinse water, acid and caustic solutions and rust inhibitors*	Metal mists and fumes, and VOCs from solvents.	Rinse and quench water containing metals, cyanides, acids, alkalies, organics, and solvents.	Sludge from wastewater treatment, spent plating solutions and cyanide solutions, bath cleaning residues
Painting *Uses paints, solvents, and water.*	VOCs from paint solvents and equipment cleaning solvents, and overspray	Waste equipment cleaning water and water wash spray paint booth sump water containing paints and solvents	Leftover paint and solvents, waste paint and solvent containers, spent paint booth filters, and spent equipment.
Fiberglass Reinforced Construction *Uses fiberglass, resin, solvents, curing catalysts, and wood and plastic reinforcing materials*	VOC emissions issued during construction operations and curing and during cleaning with solvents.	Little or no wastewater generated	Waste fiberglass, gelcoat, resin, unused resin that has exceeded its shelf life, spent solvents, and used containers.
Machining and Metal Working *Uses cutting oils, lube oils, and solvents.*	VOC emissions from use of cleaning and degreasing solvents	Wastewater containing solvents, emulsified lubricating and cutting oils and coolants.	Waste cutting oils, lube oils, and metal chips and shavings.

Source: U.S. Environmental Protection Agency. *Profile of the Shipbuilding and Repair Industry*, September 1997.

Releases of toxics occur as on-site discharges, including emissions to the air and discharges to water, or off-site transfers. On-site releases to the air occur as stack emissions, which are through confined air streams, such as stacks or vents, and fugitive emissions, which include equipment leaks, evaporative losses from surface impoundments and spills, and releases from building ventilation systems. Paint chips, leftover paint and paint containers, used abrasives, wastewater treatment sludges, still bottoms, spent metal plating solutions, and metal shavings represent some of the primary residual waste from shipbuilding and repair. Surface water releases may include releases from discharge pipes as well as diffuse runoff from land, roofs, parking lots, and other facility infrastructure.

Off-site transfers represent a movement of the chemical away from the reporting facility. Except for off-site transfers for disposal, these quantities do not necessarily represent entry of the chemical into the environment. Chemicals are often shipped to other locations for recycling, energy recovery, or treatment.

Releases from manufacturing facilities have a negative impact on both ecosystems (e.g., unhealthy wildlife) and human health (e.g., respiratory problems). In general, the scale of pollution from the vessel building industry is small compared to many other industries, such as automobile manufacturing.

FACTORS THAT AFFECT IMPACT

- Number of vessels built
- Amount of chemicals used per vessel
- Efficiency of controls and efforts to reuse or recycle chemicals and other materials, including pollution prevention efforts
- Types of chemicals released - toxicity
- Population density - extent of exposure
- Environmental conditions - climate, topography, or hydrogeology affecting fate and transport of chemicals and materials in the environment

INDICATORS OF ENVIRONMENTAL IMPACT

TOXIC RELEASES

No quantified data on human health impacts or habitat and species impacts are available. According to the 1996 Toxic Release Inventory, 41 ship building and repairing facilities (SIC Code 3731) and 166 boat building and repairing facilities (SIC Code 3732) reporting to TRI released 14.3 million pounds of pollutants to the environment in 1996, as shown in the table below.

Table 6-12: Toxic Chemicals Released from Ship- and Boat Building & Repairing Facilities, 1996 (pounds per year)

SIC	Industry Type	On-Site Releases	Off-Site Releases (Transfer to Disposal)	Total Quantity Released to the Environment
3731	Ship building & repairing	2,750,991	191,201	2,942,192
3732	Boat building & repairing	11,301,287	11,007	11,312,294
-	TOTAL	**14,052,278**	**202,208**	**14,254,486**

Note: On-site releases from Section 5 of Form R. Off-site releases from Section 6 of Form R. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics. *1996 Toxics Release Inventory Public Data Release – 10 Years of Right-to-Know: Industry Sector Analyses.* December 1998 (Table 14-3).

Total production-related waste for ship and boat building and repairing totaled 24.3 million pounds of toxic chemicals in 1996. Of the total production-related toxic waste, 11 percent underwent on-site waste-management (either recycled, used for energy recovery, or treated on-site) and 27 percent was transferred off-site for waste-management.

Because chemicals have been added to the Toxic Release Inventory (TRI), deleted, or redefined over time, year-by-year tracking of releases must use a consistent set of chemicals. The following table reports only releases of "core" chemicals required to be reported in all years, 1988-1996.[10] Releases of core chemicals dropped 21 percent over this time period.

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[10] Tables for 1988 to 1996 include only chemicals that were reportable in all years for 1988 to 1996. These tables do not include, for example, chemicals added in 1990, 1991, 1994, or 1995. Because non-fibrous forms of aluminum were removed from the list in 1989, aluminum oxide is not included. Reporting

Table 6-13: Toxic Chemicals (Core) Released from Ship- and Boat Building & Repairing Facilities (SIC 3731, 3732), 1988-1996 (thousands of pounds per year)

Year	On-site Releases					Off-site	Total
	Air	Water	Under-ground injection	Direct to land	Total On-site Releases	Releases	Releases to the Environment
1988	17,235.5	1.0	0.3	17.3	17,254.0	712.1	**17,966.1**
1994	13,441.9	19.2	-	29.3	13,490.3	335.8	**13,826.2**
1995	14,583.5	29.7	-	2.0	14,615.2	253.5	**14,868.7**
1996	13,875.7	19.8	-	51.1	13,946.5	202.2	**14,148.7**

U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics. *1996 Toxics Release Inventory Public Data Release – 10 Years of Right-to-Know: Industry Sector Analyses.* December 1998 (Table 14-14).

definitions for ammonia, hydrochloric acid and sulfuric acid have also changed, and are not included in multi-year comparisons. The set of “core” chemicals differs depending on which years are being examined, so the figures in this table may not equal those in other tables that use different years.

6.3 WATER-BORNE TRAVEL

Freight ton-miles carried on water domestically increased significantly from the 1960s to about 1998, increasing from 413 billion ton miles in 1960 to 922 billion in 1980. Since then, freight travel on water has declined to 854 billion ton miles in 1990 and 765 billion ton miles in 1996. Water carried approximately 20 percent of freight ton miles transported in the U.S. in 1996. Meanwhile, personal travel on ferry boats makes up a very small fraction of total personal travel. In 1996, about 256 million passenger miles were traveled on ferry boats (in contrast, 2.3 trillion passenger miles were traveled in passenger cars or motorcycles).[11]

Recreational boating has increased dramatically over the past few decades, particularly in the 1960s. The inventory of recreational boats in the U.S. is estimated to have increased from 2.5 million in 1960, to 7.4 million in 1970, to 8.6 million in 1980, to 11.0 million in 1990, and 11.9 million in 1996. This is a nearly fourfold increase over the 1960 to 1996 period.

All forms of water-borne travel are responsible for a number of environmental impacts, including air pollution, habitat disruption caused by wakes and anchors, wildlife collisions, and releases of solid waste and sewage. Freight vessels in particular are also responsible for introduction of non-native species to bodies of water and releases of hazardous materials.

CRITERIA AIR POLLUTANTS

DESCRIPTION OF IMPACT

Although air pollutant emissions from maritime vessels are similar to those from other forms of transportation, there are key differences. In particular, emissions from maritime vessels tend to occur over different ecosystems than those from surface transportation. Lower quantities of total emissions make the effects of vessel emissions less pronounced than those of motor vehicles. However, emissions have been increasing rapidly by recreational boats, which has implications for urban air quality. Marine engines are major contributors of hydrocarbons (HC) and oxides of nitrogen (NOx) emissions in many areas of the country.

In order to reduce air pollution from recreational boats, the U.S. Environmental Protection Agency (EPA) is issuing regulations that will bring forth a new generation of marine engines featuring cleaner technology and providing better engine performance. The gasoline marine final rule, published in August 1996,establishes emission standards for new spark-ignition gasoline marine engines used in personal watercraft and jet boat applications. Controlling exhaust emissions from new gasoline spark-ignition (SI) marine engines is expected to result in a dramatic 75 percent reduction in hydrocarbon (HC) emissions from these engines by the year 2025.[12]

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[11] U.S. Department of Transportation, Bureau of Transportation Statistics. *National Transportation Statistics 1998* (Tables 1-10, 1-11, and Water Transport Modal Profile Table).

[12] U.S. Environmental Protection Agency, Office of Mobile Sources. “Environmental Fact Sheet: Emission Standards for New Gasoline Marine Engines.” August 1996, and “Notice of Proposed Rulemaking for New

EPA is also proposing a national program to control emissions of oxides of nitrogen (NOx) and particulate matter (PM) from large marine diesel engines. These engines are used for propulsion and auxiliary power on commercial vessels in a variety of marine applications, including fishing boats, tug and towboats, dredgers, coastal and Great Lakes cargo vessels, and ocean going vessels.[13]

FACTORS THAT AFFECT IMPACT

- Number of vessel trips
- Emissions per volume of fuel consumed, per trip, or per distance traveled, by chemical
- Distance traveled
- Engine type, age, and emissions control technology
- Fuel consumed (by type) - affects emissions per mile
- Travel characteristics: speed, acceleration, etc. - affects emissions per mile
- Climatic conditions (temperature, wind, rain, etc.) - affects dispersion/dilution of pollutants and formation of secondary pollutants
- Population density - affects number of people exposed to pollution
- Sensitivity of local ecosystems

INDICATORS OF ENVIRONMENTAL IMPACT

No data are available on the health or habitat effects of emissions from water-based travel.

In 1997, maritime vessel operations were responsible for the following emissions nationwide, including recreational vessels:

Table 6-14: Criteria Pollutant Emissions from Marine Vessel Travel, 1997

Pollutant	Quantity Emitted (thousand short tons)	Percent of total Emissions of Pollutant
Carbon Monoxide (CO)	85	0.1%
Nitrogen Oxides (NO_x)	235	1.0%
Volatile Organic Comp. (VOCs)	50	0.3%
Sulfur Dioxide (SO_2)	245	1.2%
Particulate Matter (PM_{10})	31	0.1%
Particulate Matter ($PM_{2.5}$)	22	0.3%
Lead (Pb)	NA	NA

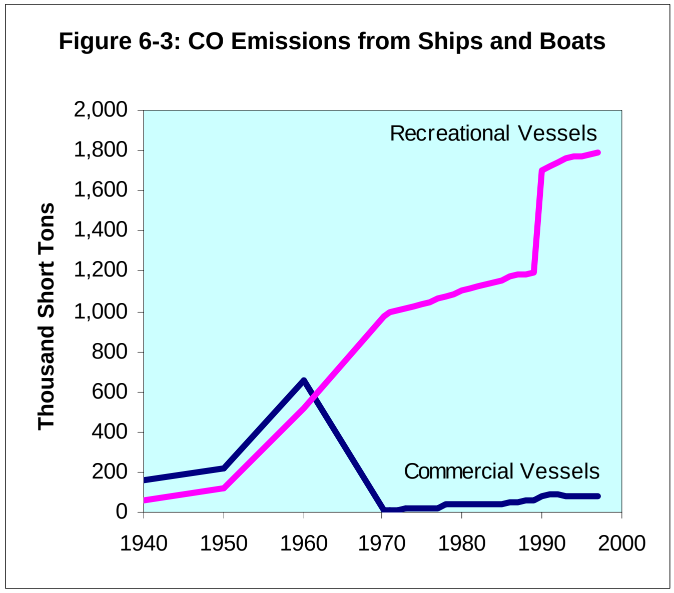
*Note: Percentage of emissions from traditionally inventoried sources (does not include agriculture and forestry, fugitive dust, or natural sources like windblown dust). Does not include recreational marine vessels.
Source: U.S. Environmental Protection Agency. *National Air Pollutant Emission Trends, 1900-1997*.

Spark-Ignition Marine Engines," Amendments 40 CFR Part 91 as published February 3, 1999 in Federal Register.

[13] U.S. Environmental Protection Agency, Office of Mobile Sources. "Regulatory Announcement: Proposed Emission Standards for New CI Marine Engines." November 1998.

Table 6-15: CO Emissions from Ships and Boats, 1940-1997

Year	Marine Vessels (TST)	Recreational Vessels (TST)
1940	155	60
1950	217	120
1960	661	518
1970	14	976
1980	37	1,102
1985	44	1,157
1990	83	1,702
1991	87	1,725
1992	85	1,744
1993	81	1,762
1994	82	1,774
1995	82	1,768
1996	82	1,780
1997	85	1,793

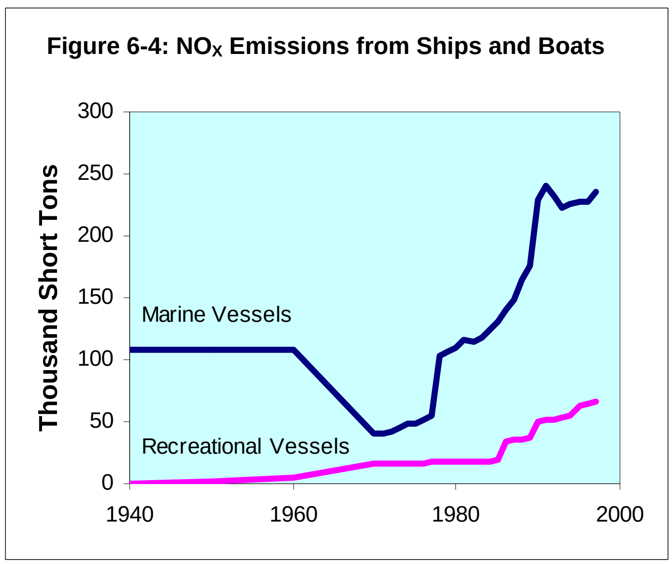


TST = Thousand Short Tons

Source: U.S. Environmental Protection Agency, *National Air Pollutant Emissions Trends, 1900-1997* (Table A-1).

Table 6-16: NO_x Emissions from Ships and Boats, 1940-1997

Year	Marine Vessels (TST)	Recreational Vessels (TST)
1940	109	1
1950	108	1
1960	108	4
1970	40	16
1980	110	18
1985	131	19
1990	229	50
1991	241	51
1992	233	52
1993	222	53
1994	225	54
1995	227	64
1996	227	65
1997	235	66



TST = Thousand Short Tons

Source: U.S. Environmental Protection Agency, *National Air Pollutant Emissions Trends, 1900-1997* (Table A-2).

Table 6-17: VOC Emissions from Ships and Boats, 1940-1997

Year	Marine Vessels (TST)	Recreational Vessels (TST)
1940	4	16
1950	108	32
1960	225	124
1970	9	350
1980	25	395
1985	30	413
1990	49	571
1991	51	578
1992	50	585
1993	48	591
1994	49	595
1995	49	435
1996	48	463
1997	50	466

TST = Thousand Short Tons
Source: U.S. Environmental Protection Agency, *National Air Pollutant Emissions Trends, 1900-1997* (Table A-3).

Figure 6-5: VOC Emissions from Ships and Boats

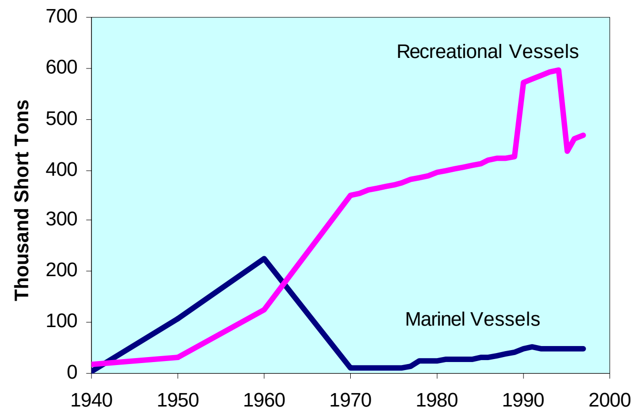


Table 6-18: SO_2 Emissions from Ships and Boats, 1940-1997

Year	Marine Vessels (TST)
1940	215
1950	215
1960	105
1970	43
1980	117
1985	143
1990	251
1991	259
1992	258
1993	249
1994	252
1995	239
1996	237
1997	245

TST = Thousand Short Tons
Source: U.S. Environmental Protection Agency, *National Air Pollutant Emissions Trends, 1900-1997* (Table A-4).

Figure 6-6: SO_2 Emissions from Ships and Boats

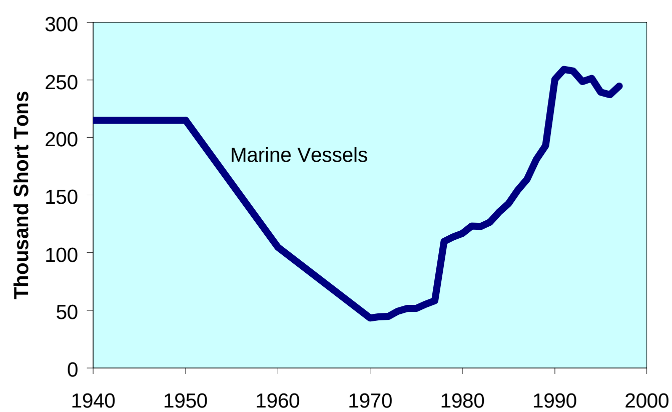


Table 6-19: PM_{10} Emissions from Ships and Boats, 1940-1997

Year	Marine Vessels (TST)	Recreational Vessels (TST)
1940	12	0
1950	19	1
1960	16	1
1970	6	NA
1980	17	24
1985	20	25
1990	31	30
1991	33	30
1992	32	31
1993	31	31
1994	31	31
1995	30	31
1996	30	32
1997	31	32

TST = Thousand Short Tons
Source: U.S. Environmental Protection Agency, *National Air Pollutant Emissions Trends, 1900-1997* (Table A-5).

Figure 6-7: PM_{10} Emissions from Ships and Boats

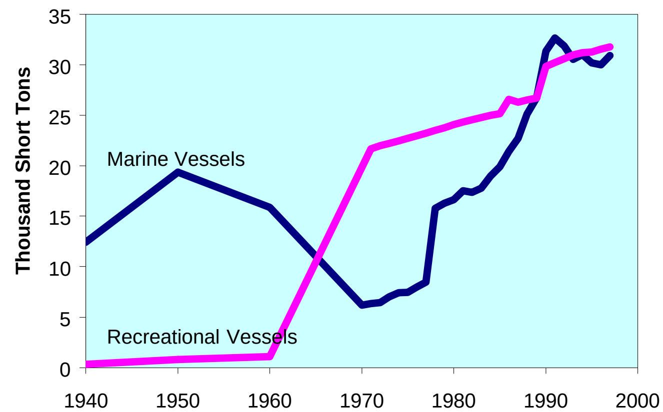
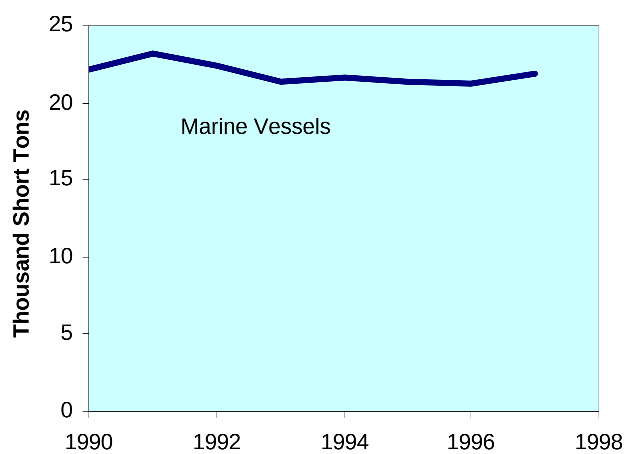


Table 6-20: $PM_{2.5}$ Emissions from Ships and Boats, 1940-1997

Year	Marine Vessels (TST)
1990	22
1991	23
1992	22
1993	21
1994	22
1995	21
1996	21
1997	22

TST = Thousand Short Tons
Source: U.S. Environmental Protection Agency, *National Air Pollutant Emissions Trends, 1900-1997* (Table A-6).

Figure 6-8: $PM_{2.5}$ Emissions from Ships and Boats



GREENHOUSE GASES

DESCRIPTION OF IMPACT

Greenhouse gases such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are emitted during maritime travel. The adverse environmental and health effects associated with increasing greenhouse gas concentrations in the atmosphere include global warming and the possibility of rising ocean levels and increased catastrophic weather activity.

FACTORS THAT AFFECT IMPACT

- Amount of travel by ships and boats
- Type of vessel
- Type of fuel consumed

INDICATORS OF ENVIRONMENTAL IMPACT

CARBON DIOXIDE

Fossil fuel combustion in water-borne travel is responsible for about 2.9 percent of CO_2 emissions from transportation, or about 0.9 percent of carbon dioxide emissions from fossil fuel combustion nationwide.[14]

Table 6-21: Carbon Dioxide Emissions from Fossil Fuel Combustion in Water-borne Travel (Million Metric Tons of Carbon)

Year	Motor Gasoline (Recreational Boats)	Distillate Fuel Oil (Diesel) (Freight ships)	Residual Fuel Oil (Freight ships)	Total Maritime Travel
1990	4.6	5.0	6.7	16.3
1991	4.8	4.8	5.5	15.1
1992	4.7	5.1	5.5	15.3
1993	4.6	4.6	4.2	13.4
1994	4.5	4.6	4.6	13.7
1995	5.3	4.3	2.9	12.5
1996	5.4	4.6	3.1	13.1

Source: U.S. Environmental Protection Agency. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1996.* March 1998 (Table 2-6).

NITROUS OXIDE AND METHANE EMISSIONS

Maritime vessels emitted a small amount of other greenhouse gases, as reported in Table 6-21:

[14] Carbon dioxide emissions from fuel combustion in 1996 are estimated at: 57.4 million metric tons of carbon (MMTCE) for air transportation; 445.5 MMTCE for transportation as a whole; 1,450.3 for all sources. Source: U.S. Environmental Protection Agency. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1996.* March 1998 (Table 2-6).

Table 6-22: Nitrous Oxide and Methane Emissions from Water-borne Travel, 1996

Pollutant	Thousand metric tons of gas	Million metric tons of carbon equivalent
Methane (CH_4)	8	<0.05
Nitrous Oxide (N_2O)	2	0.2

Source: U.S. Environmental Protection Agency, Office of Policy, Planning and Evaluation. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1996.* March 1998 (Tables 2-12, 2-13, 2-14, 2-15).

HABITAT IMPACTS FROM WAKES AND ANCHORS

DESCRIPTION OF IMPACT

Several environmental impacts result from the wakes of large or high-speed maritime vessels and anchoring. Wakes from large (e.g., cruise ships) or fast-moving vessels can cause erosion and vegetative and coral damage in confined or shallow waters. Wakes can cause strong wave propagation that is capable of eroding shorelines or stirring up bottom sediments in shallow areas. Vegetation can be disturbed both by erosion processes and sedimentation resulting from wakes. Sedimentation reduces the amount of sunlight available for photosynthetic processes. Corals also are susceptible to damage from sediments that have been suspended by the action of wakes. The impacts of wakes are local in nature and likely to be more pronounced in confined, high traffic areas.

Dropping of anchors from vessels, like wakes, can cause local habitat damage. This damage occurs through direct physical disruptions, as anchors are dropped on habitats and sometimes dragged through them. Anchor damage can be especially serious in highly productive but sensitive ecosystems, such as coral reefs.

FACTORS THAT AFFECT IMPACT

- Volume of vessel traffic
- Size of vessels
- Speed of vessels
- Number of anchors dropped
- Sensitivity of local ecosystems to physical abuse
- Number of foreign ships entering U.S. waterways
- Lack of proper disposal or exchange of ballast water or other contaminated cargo
- Enforcement of ballast water management

INDICATORS OF ENVIRONMENTAL IMPACT

The total area of shoreline erosion caused by wakes and the amount of vegetation and coral damaged and species affected by wakes and anchors is not known. No data have been found regarding the number of anchors dropped, the amount of traffic, or the average size and speed of boats in sensitive locations.

HABITAT IMPACTS FROM INTRODUCTION OF NON-NATIVE SPECIES

DESCRIPTION OF IMPACT

The inadvertent introduction of non-native species to new habitats by marine craft may result in severe environmental strain or damage to a functioning ecosystem. Non-native species may compete with native species for food and force out existing creatures. For example, the zebra mussel, a non-native nuisance species, probably entered the Great Lakes through discharge of ballast water from an oceangoing vessel. The mussels could potentially disrupt the food web in the lakes by devouring microscopic plants that form the foundation of the web. Colonies of zebra mussels also clog water intake pipes to power plants and water treatment facilities.[15] Other non-native species may out-compete existing species, resulting in significant alterations to the aquatic ecosystem.

Slow moving marine species, especially large mammals and reptiles, are often victims of encounters with motorized vessels. Fauna can be killed or severely injured through collisions with propellers or hulls. Some of the most publicized and damaging U.S. incidents involve endangered species, such as the West Indian manatee, the right whale, and various species of sea turtles. Propellers are a significant source of injuries and deaths for the West Indian manatee in coastal Florida.

FACTORS THAT AFFECT IMPACT

- Number of foreign ships entering U.S. waterways
- Lack of proper disposal or exchange of ballast water or other cargo
- Lack of enforcement of ballast water management

INDICATORS OF ENVIRONMENTAL IMPACT

No data are available on the damages to ecosystems or species loss due to introduction of nonnative species to habitats via boat nationally. Impacts in specific locations, however, are known. For example, over 130 non-native species have been introduced to the Great Lakes since 1800, and nearly a third are believed to have been carried in by ships.

Source: Council on Environmental Quality. *Environmental Quality 1993.*

OIL SPILLS AND OTHER HAZARDOUS MATERIALS INCIDENTS

DESCRIPTION OF IMPACT

Releases of hazardous materials, especially petroleum products, from vessels are one of the most publicized impacts of maritime transportation. Many factors determine the extent of damages caused by petroleum spills, including type of oil spilled (crude or refined), quantity spilled, distance of release from shore, time of year, weather conditions, water temperatures, and currents.

[15] Council on Environmental Quality. *Environmental Quality 1993.*

When an oil spill occurs, toxic hydrocarbons, such as benzene and toluene, cause immediate wildlife deaths. Shellfish and nonmigratory fish, especially those in the larval stage, are the most susceptible to these chemicals. Other chemicals form sticky, tarlike globs on the surface that adhere to marine wildlife such as birds, otters, and seals, as well as to sand, rocks, and almost all other substances. Many animals that come into contact with such chemicals die from drowning or loss of body heat. Heavy components of oil that sink to the bottom of bodies of water may have the most profound impacts on ecosystems. Such pollution can kill or damage benthic organisms and adversely affect food webs. Studies of some oil spills have shown that it takes most species of marine life three years to recover from exposure to large quantities of crude oil. Recovery times may be much longer (10 or more years) for exposure to refined oil, especially in areas with weak currents or cold waters.[16] Oil pollution in the vicinity of shorelines can cause ecological harm in coastal ecosystems.

Humans also experience health effects from oil spills. Exposure is dependent on how much oil washes ashore and how much seafood is contaminated and eaten. Some of the chemicals resulting from spills, such as benzene, are highly toxic to humans.

Ecosystems and humans also experience impacts from maritime spills of non-petroleum hazardous waste. Such spills can lead to wildlife kills, unswimmable and unfishable waters, shellfish bed closures, and human exposure through contact and food. In addition, some hazardous substance may undergo biological amplification in food chains, causing serious damage to organisms at high trophic levels. Human contact with non-petroleum hazardous waste spills can be greater when a hazardous substance spill goes undetected and warnings are not given to avoid body-contact through water recreation.

FACTORS THAT AFFECT IMPACT

- Quantity of hazardous materials transported
- Accident or spill rate
- Type and quantity of material released
- Toxicity/hazard of materials released
- Effectiveness of cleanup efforts

INDICATORS OF ENVIRONMENTAL IMPACT

OIL SPILLS

In 1996, there were 5,295 oil spills in U.S. navigable waters during vessel travel, involving nearly 1.6 million gallons of oil. In addition, 424,000 gallons of oil were spilled from non-vessel incidents, such as from facilities, pipelines, and other shoreside marina sources.

[16] Miller, G. Tyler, Jr. *Living in the Environment: An Introduction to Environmental Science.* Belmont, CA: Wadsworth Publishing Company, 1990.

Table 6-23: Oil Spills in U.S. Navigable Waters from Vessel Incidents (Number of Incidents and Volume, in thousands of gallons), 1982-1996

Year	Tankships		Tank Barges		Other Vessels,		Vessels, total	
	Incidents	Volume	Incidents	Volume	Incidents	Volume	Incidents	Volume
1982	279	1,220	547	2,147	1,383	412	2,209	3,779
1983	258	146	523	1,808	1,444	379	2,225	2,332
1984	238	4,664	499	2,484	1,530	1,863	2,267	9,012
1985	164	732	385	3,684	1,113	447	1,662	4,863
1986	196	1,165	516	1,510	900	161	1,612	2,836
1987	158	1,547	413	550	1,208	848	1,779	2,946
1988	222	852	486	3,164	1,300	370	2,008	4,386
1989	200	11,272*	504	747	1,564	675	2,268	12,694*
1990	249	4,977	458	1,042	1,779	418	2,486	6,437
1991	220	92	428	241	1,780	397	2,428	730
1992	193	118	322	149	4,795	398	5,310	665
1993	172	70	314	698	4,944	410	5,430	1,177
1994[a]	174	69	385	877	4,736	331	5,295	1,277
1995[r]	146	154	367	1,114	3,030	355	3,543	1,624
1996[a]	49	283	90	542	3,512	753	3,651	1,578

*Includes Exxon Valdez spill

Source: U.S. Department of Transportation, Bureau of Transportation Statistics. *National Transportation Statistics 1998* (Table 4-42).

HAZARDOUS MATERIAL INCIDENTS

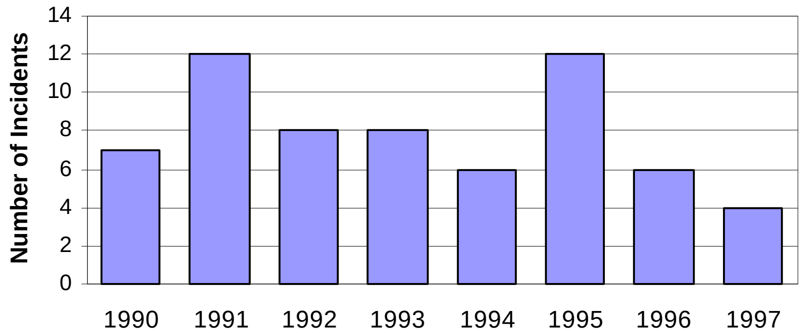
The number of maritime hazardous materials incidents is small: 12 or less per year over the period 1990-1997. No information is available on the outcomes of hazardous materials incidents, such as number of species affected.

Table 6-24: Maritime Hazardous Materials Incident Totals, 1990-1997

Year	Number of Incidents	Gallons Released	Pounds Released	Cubic Feet Released	MilliCuries Released+	Clean Up & Product Loss Damages
1990	7	102.76	0	0	0	$68,698
1991	12	191.38	164.3	0	0	$114,045
1992	8	5,499.19	0	0	0	$115,115
1993	8	2,844.35	0	0	0	$187,591
1994	6	460	0	0	0	$84,003
1995	12	1,244.55	0	0	0	$162,711
1996	6	10,282.50	0	0	0	$82,006
1997	4	300.13	0	0	0	$28,145

* Due to multiple classes being involved in a single incident, the totals above may not correspond to the totals in other reports. + MilliCuries (mCi) are a measure of radioactivity.
Source: U.S. Department of Transportation, Research & Special Programs Administration (RSPA). *Hazardous Materials Information System.*

Figure 6-9: Maritime Hazardous Materials Incidents, 1990-1997



Corrosive materials constituted the class of hazardous materials with the largest number of reported incidents — 4 — in 1997, as shown in the following table.

Table 6-25: Maritime Hazardous Materials Incidents, 1997

Hazard Class	Number of Incidents[1]	Gallons Released*	Pounds Released*	Cubic Feet Released*	MiliCuries Released*[2]	Clean Up & Product Loss Damages
Corrosive Material	3	50.13	0	0	0	$21,145
Flammable - Combustible Liquid	2	250	0	0	0	$7,000
Other Classes	0	0	0	0	0	$0
TOTALS	4	300.13	0	0	0	$28,145

1 The total for incident number is not equal to the sum of incidents by hazard class, because one incident may be reported under two or more hazard classes. The total for incidents does not double count incidents reported under multiple classes.
2 MilliCuries (mCi) are a measure of radioactivity.
*Quantities shown are the total of all reported releases. For some incidents, the quantity released is unknown and, therefore, not included in the hazard class or mode totals.
Source: U.S. DOT, Research & Special Programs Administration (RSPA), Hazardous Materials Information System (HMIS)

SOLID WASTE AND SEWAGE DUMPING

DESCRIPTION OF IMPACT

The three major types of shipboard solid waste are domestic garbage (e.g., galley waste and food packaging), operational garbage (e.g., used fishing gear, fish processing materials, and items used for onboard maintenance), and cargo-related garbage (e.g., packaging materials and dunnage). While garbage generation is substantial for U.S. maritime sectors, quantifying the amount of garbage dumped overboard is difficult. Maritime travel is not the source of all marine debris. Land-based sources and stationary maritime sources, such as oil platforms, account for some portion of marine debris. Even data on garbage generation are highly uncertain. Other factors, such as the extremely large distances (often across international borders) that floatable debris can travel, complicate statistics about vessel garbage. While these uncertainties affect the accuracy of indicators, the impacts of debris from vessels are genuine and can be described to some extent.

The most readily observable ecological effects of solid waste dumping from marine vessels are entanglement, ingestion, and ghost fishing. Entanglement occurs when wildlife come into contact with marine debris and become trapped. Affected wildlife includes mammals, turtles, birds, fish, and land animals that inhabit coastlines. Researchers believe that substantial numbers of animals die or are injured because of entanglement. In fact, entanglement is thought to be the cause of serious population declines among some species. Non-deadly injuries can be serious, causing inability to breathe, swim, feed, or raise young properly.[17]

Ingestion refers to instances in which animals swallow debris. The most publicized cases of ingestion involve sea turtles and cetaceans swallowing plastic waste. Ingestion of plastic and other debris can cause immediate death or result in a number of injuries or handicaps to wildlife. While very little data describes the extent of damage caused by ingestion, many anecdotal cases have been documented.[18]

Ghost fishing involves lost or discarded fishing gear that continues to catch finfish and shellfish. The extent of this problem is not well documented, but evidence suggests some lobster, crab, and other fisheries experience depletion due to ghost fishing. Most of the problems from ghost fishing are caused by lost or discarded trapping devices, such as gill nets. Other possible ecological effects of overboard dumping have not been researched extensively. Effects on coral reefs, water and sediment toxicity, invertebrates, plants, bottom habitats, and other areas may be substantial, but are not well documented.[19]

In addition to ecological problems, shipboard solid wastes that are dumped overboard can cause human health problems. These problems are most notably associated with direct human contact with debris. Examples of this type of problem include wounds on beaches from sharp debris that washes up on or near shore and injuries caused by contact with hazardous chemicals. Other human health hazards associated with debris include diver entanglement and boat collisions and malfunctions. While human health impacts from overboard dumping of solid waste are possible, data on exposure are unavailable.

Sewage dumping is also a problem for the marine environment. The popularity of recreational boating in coastal areas has spurred rapid development of marinas, many of which are not equipped to collect and process sewage. Boaters who use these marinas often dump sewage in the water, rather than transporting it to proper pump-out facilities. Even in cases where marinas or ports are equipped with sewage collection facilities, many vessels are still responsible for sewage pollution. Some vessels do not contain a marine sanitation device (boat toilet), and, as a result, boaters sometimes dump sewage overboard. Some vessels are equipped with marine sanitation devices that are meant to treat sewage and dump it in the water. If these devices are functioning improperly, untreated sewage can be dumped. Fees for pump-out of sewage holds on vessels also give boaters the incentive to dump sewage illegally.

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[17] National Research Council, Marine Board. *Clean Ships, Clean Ports, Clean Oceans: Controlling Garbage and Plastic Wastes at Sea.* National Academy Press. 1995.

[18] National Research Council, Marine Board. *Clean Ships, Clean Ports, Clean Oceans: Controlling Garbage and Plastic Wastes at Sea.* National Academy Press. 1995.

[19] National Research Council, Marine Board. *Clean Ships, Clean Ports, Clean Oceans: Controlling Garbage and Plastic Wastes at Sea.* National Academy Press. 1995.

Sewage from vessels can cause serious local impacts on water quality and human health, especially in areas of high recreational boat use. Studies in Puget Sound, Long Island Sound, Narragansett Bay, and Chesapeake Bay have shown that boats can be a significant source of human wastes in coastal waters, especially where the volume of boat traffic is high and hydrologic flushing is low. The two major impacts of sewage discharges are introduction of microbial pathogens into the environment and reduction in dissolved oxygen levels. Waterborne bacteria and/or viruses that enter waterways from vessel sewage discharges can cause serious ailments and diseases, such as acute gastroenteritis, hepatitis, typhoid, and cholera.[20] Many marinas are located in or near shellfish growing areas, and sewage dumped from the boats or at marinas has the potential to contaminate. Pathways of exposure for humans include both direct water contact and ingestion of contaminated seafood.

Vessel sewage has a high capacity for reducing dissolved oxygen in bodies of water. Although the volume of wastewater discharged from vessels is typically small, the organic substances in the wastewater are highly concentrated. These organics can lead to low levels of dissolved oxygen where vessel traffic is high.

Another effect of vessel sewage occurs when treated wastewaters are discharged from vessels. These wastewaters are treated with chemical additives, such as chlorine and formaldehyde, which are generally toxic to marine life.[21] Vessel sewage that is removed from vessels at pump-out facilities is typically transported to POTWs for treatment. Impacts of wastewater discharges from POTWs, therefore, are partially attributable to vessel sewage in some cases.

FACTORS THAT AFFECT IMPACT

- Quantity of food, packaging, fishing equipment, and other items used on vessels
- Vessel traffic, especially recreational vessel traffic in an area
- Poor siting of marinas near shellfish beds
- Poor flushing of marina areas
- Lack of functional marine sanitation devices on vessels
- Lack of pump-out facilities at marinas
- Inaccessibility, crowding, or malfunction of pump-out facilities at marinas

INDICATORS OF ENVIRONMENTAL IMPACT

National indicators of the environmental impacts of sewage releases and solid waste from boats and vessels are not available. Estimates of impacts to individual species, however, are available.

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[20] U.S. Environmental Protection Agency. *Guides to Pollution Prevention: The Marine Maintenance and Repair Industry*. 1991.

[21] U.S. Environmental Protection Agency. *Guides to Pollution Prevention: The Marine Maintenance and Repair Industry*. 1991.

WATER POLLUTION AND SEWAGE SANITATION

In 1990, pollution from boating and marinas affected 25 percent of the harvest-limited shellfishing waters in half of the shellfish producing states (harvest-limited waters are those in which shellfish beds may be contaminated).

Source: Council on Environmental Quality. *Environmental Quality.* 1993.

In a survey of 3,561 miles ocean shoreline waters (in 11 states nationwide), marinas were reported to be a source of pollution on 116 miles, or 3 percent of surveyed miles. In total, 467 miles of ocean shoreline were reported as impaired. As a result, marinas were reported as a source of pollution on 25 percent of impaired river miles. This pollution could be from a variety of factors, including oil spills, sewage, and other waste.

Source: U.S. Environmental Protection Agency. *Appendixes from the National Water Quality Inventory:1996 Report to Congress.* http://www.epa.gov/OW/resources

Estimates of the total amount of sewage dumped by vessels in U.S. waters are not readily available. It is estimated that 90 to 95 percent of commercial U.S. vessels have marine sanitation devices on board. 75 to 80 percent of recreational vessels have marine sanitation devices on board.

Source: U.S. Coast Guard.

INGESTION/ENTANGLEMENT IN GARBAGE DEBRIS

As many as 50,000 northern fur seals die annually from entanglement in plastic marine debris, primarily fishing nets and strapping bands. The amount of this debris attributable to vessels as opposed to land-based sources and other marine sources is unknown.

Cases of entanglement have been recorded for 51 of the world’s 312 seabird species and 10 of the world’s 75 cetacean species.

Ingestion of plastic debris has been recorded for at least 108 species of seabirds and 33 species of fish.

Source: National Research Council, Marine Board. *Clean Ships, Clean Ports, Clean Oceans: Controlling Garbage and Plastic Wastes at Sea.* National Academy Press. 1995.

GARBAGE GENERATION

The U.S. maritime sector generates an estimated total of 825,168 metric tons of garbage annually. The quantity of garbage disposed by vessels at sea is unknown.

Table 6-26: Estimated Annual Garbage Generation by U.S. Maritime Sectors[22]

Vessel Type	Number of Vessels	Annual Garbage Generation (metric tons)	Typical Voyage Area
Recreational Boats	7,300,000	159,900	Nearshore
Fishing Vessels	129,000	230,500	Nearshore and Offshore
Cargo Ships	7,800	111,700	Offshore
Day Boats	5,200	57,623	Nearshore and Offshore
U.S. Navy Vessels	284	10,262	Nearshore and Offshore
U.S. Coast Guard Vessels	2,316	4,058	Nearshore and Offshore
U.S. Army Vessels	580	254	Nearshore and Offshore
School Boats	14	358	Nearshore and Offshore
Offshore Industry Service	1,500	7,665	Nearshore and Offshore
Navy Combatant Surface	360	37,812	Offshore
Passenger Cruise Ships	128	201,830	Nearshore
Research Vessels	125	1,779	Nearshore and Offshore
Misc. Private Industry Vessels	85	1,427	Nearshore and Offshore
Total	**7,447,392**	**825,168**	

Source: National Research Council, Marine Board. *Clean Ships, Clean Ports, Clean Oceans: Controlling Garbage and Plastic Wastes at Sea.* National Academy Press. 1995.

[22] This table depicts garbage generation by U.S. fleets, not overboard dumping. Some of the generated wastes, however, are dumped overboard. Many of the vessels generate some portion of their wastes while operating in non-U.S. waters. Data were collected from various sources dating from 1990 to 1994. Number of vessels was tabulated as follows: Recreational boats: boats registered in coastal states or in states bordering the Great Lakes. Cargo Ships: different ships of all flags calling at U.S. ports.

6.4 MARITIME TERMINAL OPERATION

Maritime transport requires support facilities such as ports for loading and unloading cargo and people, repair and maintenance facilities, fueling stations, and marinas. Terminal operations for maritime vessels involve boat yards and shipyards. Boat yards typically handle recreational or small commercial boats, offering services such as painting and engine repair. Shipyards service relatively larger vessels, and often contain extensive industrial machinery. Operations may include structural repairs, painting, engine or power plant maintenance, electroplating, air conditioning and refrigeration service, and electrical repair.[23] Other terminal operations include vessel unloading and cleaning, vessel storage, and refueling. Many of the environmental impacts of these facilities are similar to those found in the shipbuilding process. Many of these activities use materials that are hazardous or may in turn generate vapors, hazardous waste, or wastewater. The actual impact of terminal activities on the environment depends on the type and volume of operations, level of cleanliness required, type of waste generated, and efficiency of treatment systems in place. Wastes from such facilities, however, can often seep into waterways and damage marine environments.

CRITERIA AIR POLLUTANTS

DESCRIPTION OF IMPACT

Air pollutants are emitted during a number of different terminal operations. Painting, a common operation in marine repair yards, involves three activities that generate wastes: surface preparation; application of paint; and equipment cleaning. Surface preparation typically involves abrasive blasting and/or chemical stripping and can cause air pollution through release of particulates, VOCs, NO_x, and SO_2. Most top-side and interior paints are not significantly toxic; however, they may emit VOCs if they are oil-based. Bottom-side paints, referred to as antifouling paints (to describe their function in preventing barnacle or other marine life growths), typically contain toxic pigments such as chromium, titanium dioxide, lead, or tributyltin compounds. The equipment used for painting must be cleaned after use, sometimes with strong cleaning solvents. Wastewaters generated from this process may contain hazardous substances, and air pollution can result as solvents volatalize.[24]

FACTORS THAT AFFECT IMPACT

- Type and level of port/marina operations
- Materials used during terminal operations

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[23] U.S. Environmental Protection Agency. *Guides to Pollution Prevention: The Marine Maintenance and Repair Industry*. 1991.

[24] U.S. Environmental Protection Agency. *Guides to Pollution Prevention: The Marine Maintenance and Repair Industry*. 1991.

INDICATORS OF ENVIRONMENTAL IMPACT

REPORTS FROM LARGE POINT SOURCES

Reports of criteria pollutant emissions from large point sources, such as marine cargo facilities, are compiled in EPA's AIRS database. These data are not complete because they do not include information from all facilities or allow consistent tracking of trends. They do, however, provide a basis for comparing the contribution of marine facilities to other large point sources. Marine cargo handling and other water transportation services contribute a very small percent of point source pollution.

Table 6-27: VOC Emissions from Marine Facilities reported to AIRS

Industry Type (SIC)	Number of Facilities Reporting	Percent of Total Facilities	Pollutant Emissions (tons/year)	Percent of Total Emissions
4491 - Marine Cargo Handling	8	0.21%	4,103	0.23%
4499 - Water Transportation Services, Nec	1	0.03%	1,216	0.07%
TOTAL - Maritime Maintenance, Support, and Operations	**9**	**0.24%**	**5,319**	**0.30%**

Source: U.S. Environmental Protection Agency, Office of Air and Radiation. *AIRS Database*. January 1999.

Table 6-28: CO Emissions from Marine Facilities reported to AIRS

Industry Type (SIC)	Number of Facilities Reporting	Percent of Total Facilities	Pollutant Emissions (tons/year)	Percent of Total Emissions
TOTAL - Maritime Maintenance, Support, and Operations	**0**	**-**	**0**	**-**

Source: U.S. Environmental Protection Agency, Office of Air and Radiation. *AIRS Database*. January 1999.

Table 6-29: NO_2 Emissions from Marine Facilities reported to AIRS

Industry Type (SIC)	Number of Facilities Reporting	Percent of Total Facilities	Pollutant Emissions (tons/year)	Percent of Total Emissions
4463 - Marine Cargo Handling(1977)	1	0.02	705	0.01
4491 - Marine Cargo Handling	1	0.02	372	0
TOTAL - Maritime Maintenance, Support, and Operations	**2**	**0.04**	**1,077**	**0.01**

Source: U.S. Environmental Protection Agency, Office of Air and Radiation. *AIRS Database*. January 1999.

Table 6-30: SO_2 Emissions from Maritime Marine Facilities reported to AIRS

Industry Type (SIC)	Number of Facilities Reporting	Percent of Total Facilities	Pollutant Emissions (tons/year)	Percent of Total Emissions
4491 - Marine Cargo Handling	1	0.04%	670	0
TOTAL - Maritime Maintenance, Support, and Operations	**1**	**0.04%**	**670**	**0**

Source: U.S. Environmental Protection Agency, Office of Air and Radiation. *AIRS Database*. January 1999.

Table 6-31: PM_{10} Emissions from Marine Facilities reported to AIRS

Industry Type (SIC)	Number of Facilities Reporting	Percent of Total Facilities	Pollutant Emissions (tons/year)	Percent of Total Emissions
4491 - Marine Cargo Handling	2	0.18%	272	0.06%
TOTAL - Maritime Maintenance, Support, and Operations	**2**	**0.18%**	**272**	**0.06%**

Source: U.S. Environmental Protection Agency, Office of Air and Radiation. *AIRS Database.* January 1999.

WASTES: TOXICS, WASTEWATER, AND SOLID WASTE

DESCRIPTION OF IMPACT

Wastes are produced during various processes at marine terminals, as summarized in the table below.

Table 6-32: Wastes Associated with Marine Vessel Terminal Operations:

Process	Air toxic waste	Wastewater & other fluid wastes	Solid waste
Air emissions from storage tanks and open processing equipment emissions	VOC emissions		
Grit blasting and chemical stripping	VOC emissions	Wastewater containing blasting media, organic paint sludges, heavy metals, and stripping chemicals	Paint chips, spent abrasives, surface contaminants, and cargo tank residues.
Spray painting, resin application	VOC emissions	Waste paints, thinners, degreasers, solvents, resins and gelcoat	Surface contaminants, and cargo tank residues
Engine Repair	VOC emissions	Waste turbine oil, lubricants, degreasers, mild acids, batteries, and carburetor cleaners	
Electroplating/metal finishing		Cyanide solutions, heavy metal sludges, corrosive acid, and alkali solutions	Sludge from wastewater treatment, spent plating solutions and cyanide solutions, bath cleaning residues
Machine shops	VOC emissions	Spent cutting and lube oils, scrap metal, and degreasers	Waste cutting oils, lube oils, and metal chips and shavings.
Equipment cleaning, area washdown		Wastewater containing paints, solvents, oils, and degreasers	
Degreasing, equipment cleaning, chemical paint stripping, reinforced plastic fabrication	VOC emissions	Resin and paint contaminated solvents	
Vessel bilge cleaning		Bilge wastes (oily water)	

Sources: U.S. Environmental Protection Agency. *Guides to Pollution Prevention: The Marine Maintenance and Repair Industry.* 1991. U.S. Environmental Protection Agency. *Profile of the Shipbuilding and Repair Industry.* September 1997.

The cleaning of tank interiors is a major source of waste. Wastewater volumes and characteristics vary depending on the cargo transported, the cleaning solution used, the tank size, and other factors. Residual cargo, or tank heels, must be removed, using the vehicle's own cargo transfer piping, pumps at the cleaning facility, or manually. In barges and ships, volumes can be large and their removal, called "stripping," is often carried out using a built-in vessel stripping system. Pumping ballast water into some of the tank compartments to tilt the vessel can facilitate stripping of heels from barges and ships.[25] Another common waste is bilge waste, which contains wastewater mixed with oil and fuel, and is actually generated by the vessels themselves.[26]

Other sources of wastes include engine repair work, cargo unloading, and vessel refueling. Engine repair work on small boats produces various wastes, including lube oils, hydraulic fluids, waste fuels, hydrocarbon solvents, and batteries. Larger shipyards produce higher quantities of engine-related waste and may generate supplementary wastes, such as machine shop cutting fluids and other degreasing and cleaning solvents.

Vessel unloading results in air pollutant emissions from the displacement of vapors as liquids are loaded into cargo holds either directly through open-hatches or from pipe header systems which collect the vapors and vent to the atmosphere. Releases of hazardous materials or other pollutants can occur during loading and unloading or through dust emissions. For example, portions of fertilizer shipments are sometimes spilled in waterways or dust from movement of fertilizer shipments enters waterways.

Refueling causes problems similar to those of auto refueling stations. One major difference, however, is that spills can enter waterways directly during marine refueling. Like auto refueling, VOC can be emitted in vapors. Underground storage tanks used to hold vessel fuels can also leak their contents into waterways.

Creosote treated wood is used throughout marine installations in wharves, jetties, breakwaters, etc., bridges, dams, and foundation piling. While coal tar creosote is one of the most effective of the oil soluble preservatives, this preservative is highly toxic. It prevents organisms from attacking wood and is relatively insoluble in water. Because it is a hazardous material, it is unavailable for boat building applications. However, some older vessels with deadwood, keel, stems and heavy timbers which were originally treated with creosote, are still in service, and creosote on treated wood in marine installations could be released into the environment.

The nature of wastes and emissions generated by terminal operations makes them harmful to many forms of life, including humans. Humans can be exposed to toxicants directly (e.g., through swimming in polluted waters or breathing polluted air) or indirectly (e.g., through eating seafood that has ingested toxicants). Non-toxic pollution, such as excessive nutrient loading caused by fertilizer releases from loading docks, damages ecosystems. Such releases can cause algal blooms, which degrade water quality (often by reducing the quantity of dissolved oxygen).

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[25] U.S. Environmental Protection Agency. *EPA Office of Compliance Sector Notebook Project: Profile of the Transportation Equipment Cleaning Industry.* September 1995, p. 17.

[26] U.S. Environmental Protection Agency. *Guides to Pollution Prevention: The Marine Maintenance and Repair Industry*. 1991.

FACTORS THAT AFFECT IMPACT

- Number of terminals
- Type and level of terminal operations
- Materials used during terminal operations
- Fugitive material collection systems in place at port facilities
- Wastewater treatment capabilities

INDICATORS OF ENVIRONMENTAL IMPACT

Data on water quality, habitat, and health impacts associated with maritime vessel terminal operations are not available.

WASTE WATER

Data on water quality impacts to streams, rivers, and lakes, and related habitat due to maritime terminal operations are not available.

Estimated average heel volume from tank barges is 5 to 500 gallons per tank, and average wastewater generated from tank barges is 10,000 to 12,000 gallons per tank. Some facilities discharge directly to surface waters under NPDES permits or to underground injection wells under Safe Drinking Water Act permits.

Source: U.S. Environmental Protection Agency. *EPA Office of Compliance Sector Notebook Project: Profile of the Transportation Equipment Cleaning Industry*. September 1995, p. 21.

HAZARDOUS AIR POLLUTANTS

Marine vessel loading and unloading operations are believed to emit as many as 60 of the 189 hazardous air pollutants (HAPs) defined in the Clean Air Act Amendments, including benzene, toluene, ethyl benzene, and xylene. Approximately 350 facilities emitted 8,000 metric tons of HAPs in 1990.

Source: U.S. Environmental Protection Agency. *National Air Quality and Emission Trends Report 1993.* 1994.

Data on other wastes generated from marine vessel terminal operations have not been estimated at the national level.

6.5 DISPOSAL OF VESSELS AND PARTS

SOLID WASTE

DESCRIPTION OF IMPACT

The major impact of vessel scrappage is landfilling of non-recycled parts, some of which contain toxic components (e.g., batteries). The contribution of boat scrappage to problems associated with landfilling and hazardous waste disposal is unknown.

FACTORS THAT AFFECT IMPACT

- Number of vessels scrapped
- Size of vessels
- Use of hazardous materials in vessels
- Disposal method/fraction disposed of properly (recycling, recovery, etc.)
- Recovery rate of materials in scrapped vessels

INDICATORS OF ENVIRONMENTAL IMPACT

Estimates are not available on the health and environmental impacts of landfilling or other disposal of scrapped vessels. Data on the number of vessels scrapped/recycled annually in the U.S. have not been identified. The large increase in the inventory of recreational vessels indicates that more vessels will eventually be disposed of than in the past; however, materials may be recycled.

7. DATA AVAILABILITY AND NEXT STEPS

A great deal of progress has been made over the past 30 years in the collection and development of data related to transportation and the environment. This chapter describes some of the primary sources of information about transportation and the environment. The focus here is on environmental outputs, such as emissions, releases, and incidents, because output information tends to be more readily available than information on environmental outcomes, which tend to be identified only in special studies.

This chapter examines two categories of relevant data sources: 1) environmental data sources, and 2) transportation data sources. It provides references to data sources and web page information. Because the procedures used to collect and develop data affect reliability and usefulness in tracking trends, this chapter assesses the strengths and limitations of data. It concludes with a summary of data needs and next steps.

7.1 DATA SOURCES FOCUSED ON THE ENVIRONMENT

Environmental data systems tend to focus on individual types of pollutants separately. These data sources often provide information on the contribution of transportation and transportation-related industries to pollutant emissions or releases. They also provide information that allows the user to compare environmental outputs from different activities and sectors. Table 7-1 summarizes the major environmental databases and sources used for developing indicators for transportation. Other sources of data cited in this report are also available, but the ones listed here are produced and updated periodically, and generally allow tracking of trends. The primary data sources associated with each environmental impact are summarized below.

CRITERIA AIR POLLUTANTS

U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards (OAQPS). ***National Air Pollutant Emissions Trends Report*** **and** ***National Emission Trends (NET) Inventory Database.***
http://www.epa.gov/ttn/chief/

The *National Air Pollutant Emissions Trends* report is issued annually and contains trend data (the most recent version available contains data for 1990-1997), as well as projections of air pollutant emissions. This report is a detailed source of data on emissions from mobile sources, with data on each mode, as well as data on emissions from fuel production, distribution, and storage. Although the report provides detail on emissions associated with travel, estimates of emissions associated with other aspects of the transportation industry, such as vehicle manufacture, vehicle maintenance and support services, are not provided directly in the report. Emission estimates are reported based on industrial processes, such as metals processing or fuel combustion.

Table 7-1: Summary of Major Environment-Focused Databases and Publications

Environmental Issue	Source	Data
Criteria Air Pollutants	U.S. EPA, Office of Air Quality Planning and Standards (OAQPS). *National Air Pollutant Emissions Trends.*	Trend data on criteria pollutants (CO, VOC, NO_X, SO_2, PM_{10}, and Pb), as well as projections. A rich and detailed source of data on emissions from mobile sources (each mode), as well as industry and fuel production, distribution, and storage.
	U.S. EPA, Aerometric Information Retrieval System (AIRS) database	Estimates of criteria pollutant emissions (CO, VOC, NO_X, SO_2, PM_{10}, and Pb) from large point sources (e.g., manufacturing, airports, marine vessel loading facilities).
Greenhouse Gas Emissions	U.S. Dept. of Energy (DOE), Energy Information Administration (EIA). *Emissions of Greenhouse Gases in the United States.*	Trend data on emissions of CO_2, methane, nitrous oxide, and halocarbons.
	U.S. EPA, Office of Policy. *Inventory of U.S. Greenhouse Gas Emissions and Sinks.*	Trend data on emissions of CO_2, methane, nitrous oxide, and halocarbons, based on U.S. DOE data; includes estimates of mobile source emissions by mode.
	U.S. DOE, Oak Ridge National Laboratory. *Transportation Energy Databook.*	Trend data on energy use (in Btu) by mode of transportation (for calculating carbon dioxide emissions).
CFCs	U.S. DOE, EIA. *Emissions of Greenhouse Gases in the United States.*	Trend data on emissions of CFC-12.
Toxics	U.S. EPA, Toxic Release Inventory (TRI)	Trend data on toxic chemicals that are being used, manufactured, treated, transported or released into the environment from facilities that report to EPA. Data are collected annually and can be tabulated by SIC code.
Water Quality	U.S. EPA, Office of Water. *National Water Quality Inventory: 1996 Report to Congress.*	Contains detailed information on the state of lakes, rivers, and streams in the United States, and identifies number of states reporting different reasons (e.g., dredging, highway construction) for wetlands destruction and wetlands degradation
	U.S. EPA, Office of Underground Storage Tanks. *Corrective Action Measures Reports.*	Estimates of leaks from underground fuel storage tanks
Hazardous Materials Incidents	U.S. Dept. of Transportation, Research & Special Programs Admin. *Hazardous Materials Incidents System.*	Contains information on number of hazardous materials incidents, amount of release, deaths, and injuries annually, 1987-96 for each mode.

Data contained in the *National Air Pollutant Emission Trends* report come from the national emissions inventory maintained by EPA in the form of the National Emissions Trends (NET) inventory database. More detailed county-level data are available on the National Emission Trends CD, which also contains estimates of criteria pollutant emissions by SIC code industry. Emissions are stored by tier category and by Standard Industrial Class (SIC) at the county, nonattainment area, state, and national levels. National emissions by industry can be estimated from this database.

U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards (OAQPS). *Aerometric Information Retrieval System (AIRS) database.*
http://www.epa.gov/airs/

EPA's Aerometric Information Retrieval System (AIRS) database provides estimates of criteria pollutant emissions from large point sources. AIRS is administered by the U.S. Environmental Protection Agency (EPA), Office of Air Quality Planning and Standards (OAQPS), Information Transfer and Program Integration Division (ITPID). AIRS contains a number of sub-systems, which contain information on air quality as well as emissions from point sources. The AIRS Facility Subsystem (AFS) contains both emissions and compliance data on air pollution point sources regulated by the U.S. EPA and/or state and local air regulatory agencies, and is a source of data on pollutant emissions from transportation-related industries. AFS contains data on industrial plants and their components: stacks, the points at which emissions are introduced into the atmosphere; points, the emission point or process within a plant that produces the pollutant emissions; and segments, which are components of the processes that produce emissions. Compliance data is maintained at the plant and point levels, tracking classification status, inspections, and compliance actions. AFS also includes data for management of operating permit applications and renewals.

The AIRS database only includes emissions estimates for point sources emitting greater than or equal to 100 tons per year of volatile organic compounds (VOCs), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), or particulate matter less than 10 microns in size (PM_{10}); 1,000 tons per year of carbon monoxide (CO); or 5 tons per year of lead (Pb).

GREENHOUSE GAS EMISSIONS

U.S. Department of Energy, Energy Information Administration. *Emissions of Greenhouse Gases in the United States.*
http://www.eia.doe.gov/env/ghg.html

The U.S. Department of Energy's Energy Information Administration (EIA) develops estimates of U.S. emissions of greenhouse gases annually. Estimates of anthropogenic (human-caused) emissions of carbon dioxide, methane, nitrous oxide, and several other greenhouse gases are estimated based on accepted methodologies for converting activity and fuel consumption information into emissions.

Emissions of carbon dioxide from mobile sources are only presented by fuel type (e.g., motor gasoline, LPG, jet fuel, distillate (diesel) fuel, residual fuel, aviation gas, natural gas), not by mode of transportation. As a result, modal impacts cannot be inferred directly from the report. In addition, industrial sector emissions are not provided at a level of specificity that is sufficient to determine the effects of transportation-related manufacturing industries.

U.S. Environmental Protection Agency, Office of Policy. *Inventory of U.S. Greenhouse Gas Emissions and Sinks.*
http://www.epa.gov/globalwarming/inventory/index.html

Based on data from the Energy Information Administration, the U.S. EPA also develops estimates of greenhouse gas emissions from various sources annually. In recent reports, the EPA has calculated detailed estimates of carbon dioxide emissions by mode of transportation. The EPA has tracked emissions since 1990, and does not provide historical greenhouse gas emissions trends prior to 1990.

TOXICS

U.S. Environmental Protection Agency. *Toxic Release Inventory (TRI).*
http://www.epa.gov/opptintr/tri/

The Toxic Release Inventory (TRI) is a database of information about releases and transfers of toxic chemicals from manufacturing facilities. Facilities must report their releases of a toxic chemical to TRI if they fulfill four criteria:

1) They must be a manufacturing facility (primary SIC code in 20 -39);

2) They must have the equivalent of 10 full-time workers;

3) They must either manufacture or process more than 25,000 lbs. of the chemical or use more than 10,000 lbs. during the year;

4) The chemical must be on the TRI list of 350 specific toxic chemicals or chemical categories.

Because of these criteria, not all, or even most, pollution is reported in TRI. However, TRI does have certain advantages:

1) It is multi-media. Facilities must report the amounts they release to air, land, water, and underground separately, and must report how much they send off-site;
2) All quantities are reported in pounds. This is an advantage compared to databases like PCS (Permit Compliance System), which focus on water pollution and often report releases as concentrations, or other databases that report releases by volume of waste. These measures are often impossible to convert into pounds;
3) It is congressionally mandated to be publicly available, by electronic and other means, to everyone. This means that it is relatively easy to obtain TRI data and that the data are well known, becoming a national yardstick for measuring progress in pollution and waste generation. The TRI data is reported by individual facilities, which send their reports to EPA every year. These reports are filled out on a form called Form R. EPA converts these forms into an electronic database.

TRI does not provide information on exposure and the ultimate health impacts of the releases. Air, water, and land exposures have different effects, and some amount of the release may not come in contact with human populations. In addition, TRI chemicals have very different toxic effects. Some chemicals are much more hazardous than others are, so comparing releases on a pound-by-pound basis may not be a good predictor of comparative human health effects.

Other reports are available that estimate emissions of hazardous air pollutants (HAPs). These reports, however, do not track emissions consistently over time, and so do not serve as good sources of information for developing annual indicators. The following EPA report is an example of such a report:

U.S. Environmental Protection Agency, Emission Factors and Inventories Group and Visibility and Ecosystem Protection Group. *1990 Emissions Inventory of Forty Section 112(k) Pollutants.* January 1998.

This report contains estimates of 1990 emissions of 40 hazardous air pollutants (HAPs). It identifies rural and urban emissions from various source categories, including mobile sources (on-road vehicles, aviation, other non-road vehicles) and industry (e.g., tire manufacturing). However, for many of the pollutants, emissions are not identified by mode (emissions from non-road mobile sources are presented together) and it is not possible to identify the portion of industrial emissions from transportation-related manufacturing.

WATER QUALITY

U.S. Environmental Protection Agency, Office of Water. *National Water Quality Inventory: Biennial Report to Congress*.
http://www.epa.gov/305b/

Every two years, the U.S. Environmental Protection Agency produces a National Water Quality Inventory Report. The report is based primarily on water quality assessments submitted to the U.S. EPA by the states, territories, American Indian tribes, the District of Columbia, and interstate commissions in Section 305(b) reports. The document characterizes water quality, identifies widespread water quality problems of national significance, and describes various programs implemented to restore and protect water quality. It identifies reported causes of water quality problems, including transportation-related causes, such as dredging and road salting.

The report is limited in many respects for analyzing the impacts of transportation. Information in the report is based on information submitted by states, tribes, and other jurisdictions that do not use identical survey methods or criteria to rate water quality. Without known and consistent survey methods in place, caution must be used in comparing data submitted during different reporting period for the purpose of trend analysis. In addition, only a portion of total waters are actually surveyed. In the 1996 Report, the following percentage of waters were surveyed: rivers and streams – 19 percent; lakes, ponds, and reservoirs – 40 percent; estuaries – 72 percent; ocean shoreline waters – 6 percent; Great Lakes shorelines – 94 percent.

U.S. Environmental Protection Agency, Office of Underground Storage Tanks. *Corrective Action Measures Reports.*
http://www.epa.gov/swerust1/cat/camarchv.htm

Data on underground storage tanks (USTs) are complied in EPA’s Corrective Action Measures reports. These reports contain data on the number of active and closed tanks, releases reported, cleanups initiated and completed, and emergency responses. The reports were originally referred to as "STARS" (Strategic Targeted Activities for Results System) data and were collected on a quarterly basis. The Corrective Action Measures Reports are now available on a semi-annual basis. They do not focus solely on transportation fuel storage tanks, so it is not possible to separate transportation fuel tanks from other tanks.

HAZARDOUS MATERIALS INCIDENTS

U.S. Department of Transportation, Research and Special Programs Administration (RSPA). *Hazardous Materials Incidents System.*
http://hazmat.dot.gov/hmisframe.htm

The Hazardous Materials Information System (HMIS) is a computerized information management system containing data related to the federal program to ensure the safe transportation of hazardous materials by air, highway, rail, and water. The HMIS is the primary source of national data for the federal, state, and local governmental agencies responsible for the safety of hazardous materials transportation. It contains information on incidents involving the interstate transportation of hazardous materials by the various transportation modes.

Carriers of hazardous materials are required to report certain unintentional releases that occurred during transportation of hazardous materials. The report identifies the mode of transportation involved, name of reporting carrier, shipment information, results of the incident, hazardous materials involved, nature of packaging, cause of failure, and narrative description of the incident. This information is available in the incident database approximately three months after the receipt of the report by RSPA.

7.2 DATA SOURCES FOCUSED ON TRANSPORTATION

Some data sources provide information focused on transportation and transportation-related industries. These sources generally include information on transportation infrastructure and travel activity, and/or information on environmental effects compiled from other sources. The most important of these documents are described below.

U.S. Department of Transportation, Bureau of Transportation Statistics. *Transportation Statistics.*
http://www.bts.gov/btsprod/nts/

The Bureau of Transportation Statistics (BTS) compiles data on all modes of transportation. These data primarily focus on transportation infrastructure (e.g., miles of roads, number of airports), and travel activity (e.g., passenger miles traveled, vehicle miles traveled, freight tons carried), although information on environmental effects is cited from other sources. BTS draws from a number of information sources, including Federal Highway Administration's Office of Highway Information Management, the U.S. Coast Guard, and the Federal Aviation Administration. Specific reports utilized by BTS in data compilations include, among others:

Federal Highway Administration's *Highway Statistics*

American Association of Railroads' *Railroad Facts*

American Public Transit Association's *Transit Fact Book*

Eno Foundation for Transportation Research's *Transportation in America*

Information from BTS is useful for providing context to environmental indicators and helping to explain the reasons for changes in environmental effects.

U.S. Environmental Protection Agency, Office of Enforcement and Compliance Assurance. *Sector Notebooks.*
http://es.epa.gov/oeca/sector/

The EPA's Office of Compliance has developed a series of notebooks containing information on selected major industrial groups. These notebooks provide a comprehensive analysis of data for specific industries, including an environmental profile, pollutant release data, and information on industrial processes, pollution prevention techniques, regulatory requirements, compliance/

enforcement history, government and industry partnerships, and innovative programs. Specific sector notebooks that pertain to transportation include:

Profile of the Motor Vehicle Assembly Industry (1995)

Profile of the Ground Transportation Industry (1997)

Profile of the Aerospace Industry (1998)

Profile of the Air Transportation Industry (1997)

Profile of the Shipbuilding and Repair Industry (1997)

Profile of the Water Transportation Industry (1997)

Profile of the Transportation Equipment Cleaning Industry (1995)

These notebooks compile information from a variety of sources, including some of the environmental databases described above.

7.3 DATA GAPS

Significant progress has been made in the collection and development of data on the environmental impacts of transportation. In particular, information about the impacts of transportation on air quality is widely available. Detailed emissions inventories have been developed and a nationwide monitoring system records daily variations in air quality. The U.S. Environmental Protection Agency, with support from the U.S. Department of Transportation, is taking steps to improve the models used to estimate motor vehicle emissions in real world conditions. Detailed inventories of greenhouse gases have also been developed for the transportation sector.

Other aspects of environmental quality as they relate to transportation are less well documented. In particular, national impacts of transportation on water resources, wildlife, and habitats are less well known. The environmental impacts of transportation-related activities, such as service stations and maintenance activities, have generally not been quantified. In particular, little is known about the outcomes or end results of these activities on human health and ecosystems. Development of transportation infrastructure often facilitates increased development nearby, and these secondary impacts of transportation are also poorly understood.

Despite these gaps, understanding of the environmental implications of transportation has improved substantially over the past twenty years. Access to information has also improved dramatically, in particular due to the Internet and posting of environmental information on the World Wide Web. Most databases on environmental impacts maintained by EPA and other government agencies are available on-line. Much of this information can be searched by region, state, or county.

For the most part, however, current environmental data systems treat each kind of pollution separately, and current transportation information sources focus on individual modes. Transportation decision-makers need information that better integrates understanding of the multi-media environmental impacts of transportation and allows comparisons of multi-modal environmental performance. There is also a need for information on the comparative performance of multi-modal transportation alternatives, approaches to pollution prevention and mitigation, and the costs and benefits of environmental controls.

7.4 NEXT STEPS

This report focuses on national-level indicators of the environment impacts of transportation. It presents data to allow a user to examine the contribution of transportation to specific environmental problems, track trends over time, and compare impacts from different modes of transportation nationally. A logical next step would be to extend the focus of this effort to measures that can be used more directly by state and local decision-makers and communities to assess the environmental performance of their transportation systems and transportation alternatives. Three potential next steps are described below.

STATE / LOCAL PERFORMANCE MEASURES

Performance measures could be developed to compare the environmental performance of transportation systems or facilities in particular communities or states. Performance measures like those developed in Texas Transportation Institute's (TTI) Mobility Study (for metropolitan traffic congestion) and the American Council for an Energy Efficient Economy's (ACEEE) Green Guide (for the environmental performance of motor vehicles) are readily understood by the public and local decision-makers. A particular strength of these measures is that they highlight differences in performance in an eye catching and easy to understand manner.

Transportation-environmental performance measures could be developed at a number of levels:

- states
- metropolitan areas / urbanized areas
- counties, cities, or other sub-metropolitan areas
- transportation facilities (e.g., airport, ports)

Measures could range from a simple index (e.g., VMT per capita, lane miles per capita) to a more complex measure of environmental impacts involving a calculation procedure (e.g., emissions per capita, impervious road surfaces per capita, transportation fuel use per capita), to other measures that relate to transportation options or system performance (e.g., mode share, accessibility measures, travel costs, percent of population within 1 mile of a transit station, bicycle lane-miles per capita, range of transportation investments). Once performance measures are selected, the next step would be to collect data for a number of urban areas or states and compare the environmental performance of their transportation systems using the performance measures.

COMPARATIVE INDICATORS OF TRANSPORTATION MODES OR ALTERNATIVES

A number of reviewers who provided input to the Indicators report suggested that the report develop estimates of environmental impacts per passenger mile, per passenger trip, and/or per freight mile. These metrics would allow more direct comparisons between the environmental impacts of different modes of transportation or transportation alternatives. These metrics are somewhat limited, however, because of variations among regions and types of trips. A more detailed analysis would be useful to develop metrics that would help in examining travel options in specific regions (e.g., light rail versus highway facility; individual choices between transit, SOV, or HOV).

Research steps could involve the following:

1) Develop national average impacts based on different metrics (e.g., per passenger mile, per passenger trip), with appropriate caveats.

2) Develop impact measures (per passenger mile, per passenger trip) for specific regions or scenarios, such as shifting freight traffic between truck and rail, using local data on traffic congestion, average vehicle occupancy, etc.

3) Work with metropolitan planning organizations (MPOs) to use regional travel models, and potentially a multi-modal investment analysis tool, like FHWA's Surface Transportation Efficiency Analysis Model (STEAM), to examine the implications of multi-modal project alternatives (e.g., building light-rail versus a new highway). Synthesize the conclusions from different alternative arrangements.

TRANSPORTATION-ENVIRONMENTAL IMPACTS COMMUNICATIONS PACKAGE

Public access to environmental information is an important component of the Environmental Protection Agency's mission. Dissemination of accurate, up-to-date environmental information helps the public and government officials understand the implications of transportation decisions. National-level statistics also can be used to assess national environmental performance and progress toward meeting goals for the natural environment and human health and welfare.

Electronic dissemination of information from this report would extend the reach of these research findings. In particular, it would be beneficial to develop a user-friendly web page that allows the user to click on different environmental impacts to obtain information on the transportation sector's contribution to that impact. The web page would utilize information from this report and provide links to web sites that update their environmental databases and reports periodically.

CONCLUSION

Over the past twenty years, considerable progress has been made in reducing some of the most noticeable environmental impacts of transportation, including motor vehicle air pollution, aircraft noise, leaking petroleum from underground storage tanks, and solid waste. Challenges remain in many areas, however. Rapid growth in travel demand threatens to aggravate transportation impacts, and recognition that environmental strategies must actively identify and address interrelationships between environmental media is growing.

Historically, policies for managing the environment have focused on a technology-based approach or a project-specific approach to mitigation. In recent years, policies have shifted toward a systems-based approach, with an increasing focus on pollution prevention and avoidance of impacts. Transportation decision-making now requires analysis of multi-modal and "intelligent transportation" investment alternatives, and there is more recognition of the indirect effects of transportation on land use and the environment. In this context, research efforts to improve understanding of the impacts of transportation on the environment are more important than ever. As travel demand continues to grow, so does the need for information on the environmental performance of the transportation system and the interactions between transportation and the environment.